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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 764

Contribution from the Bureau of Markets
CHARLES J. BRAND, Chief

Washington, D. C. PROFESSIONAL PAPER July 5, 1919

FACTORS INFLUENCING THE CARRYING QUALITIES OF AMERICAN EXPORT CORN

By

E. G. BOERNER, Grain Supervisor

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By E. G. BOERNER,
Grain Supervisor.

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INTRODUCTION.

Large quantities of American corn are normally exported to Europe each year. Investigations conducted by the United States Department of Agriculture have shown that a considerable amount of the corn exported previous to the World War arrived in Europe in a heated, damaged, and spoiled condition.[1]

During the latter stages of the war the authorities who had control of the shipping of large amounts of corn to Europe took steps to insure that only such corn as would safely stand any voyage without spoiling was exported. Some of the requirements imposed were more strict than appear to be necessary under normal conditions, and, since such normal conditions will again obtain after the close of the war, the data presented in this bulletin will be of general interest to the export trade.

The carrying qualities of export corn during shipment to Europe depend for the most part on the moisture content and the quality and condition of the corn as loaded, the length of the voyage, the season of the year during which shipped, the weather conditions during the shipment, and the position of stowage of the corn in the vessel. In order to determine the influence of each of these factors under varying conditions, eight representative cargoes of corn were accompanied from the United States to various European ports, and one additional cargo (cargo No. 5) was thoroughly sampled at the time of loading in America and again at the time of discharge in Europe.[2] In the investigations covering the cargoes which were accompanied to Europe, observations and tests were made daily from the time the corn was put into the vessels until it was discharged in Europe. During the loading of these cargoes, electrical resistance thermometers were placed at various definite positions in the corn. These thermometers were extended by "leads" to the deck of the ship so that they could be conveniently connected to a temperature indicator as illustrated in figure 2, thus making it possible to obtain a record of the changes in the temperature of the corn in the various positions of stowage. The temperatures were recorded each day that the weather permitted during the voyage.

As the electrical-resistance thermometers were being placed in the corn, 3-quart samples were taken from the corn surrounding each thermometer, with which to determine the changes in the quality

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[1] These data are given in U. S. Department of Agriculture, Bureau of Plant Industry, Circular No. 55. This publication, of which J. D. Shanahan, C. E. Leighty, and the writer are the authors, is now out of print. Since the investigations reported in this bulletin are a continuation of those discussed in Circular No. 55, the subject matter discussed in that publication regarding moisture content as a factor influencing the carrying qualities of export corn, germination, and fermentation in export-corn, the keeping qualities of export corn influenced by its position of stowage in the steamship, and the length of the voyage and season of the year when shipped in relation to the carrying qualities of corn has been freely used in this bulletin in the discussion of those factors.

[2] Cargoes Nos. 1, 2, 3, and 8 were accompanied to Europe by the writer; cargoes Nos. 4 and 9 were accompanied by John H. Cox; cargo No. 6 was accompanied by Laurel Duval, and cargo No. 7 was accompanied by R. C. Miller, grain supervisors, formerly assistants in grain standardization. The investigations reported herein were made in the Office of Grain Standardization of the Bureau of Plant Industry under the direction of Dr. J. W. T. Duvel, crop technologist in charge. Since July 1, 1917, the grain standardization investigations of the Department of Agriculture have been administered by the Bureau of Markets in connection with the enforcement of the United States grain standards Act.

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and condition of the corn during the voyage. One-half of each sample was retained for analyses and the other half put into a "trap" or crossed wire container, which was then fastened to the thermometer and recovered as the corn was being discharged in Europe. The purpose of using the wire containers was to secure certain definite samples with which to correlate the effects of the changes in temperature during the voyage on corn differing in moisture content and the degree of soundness at the time of loading. As will be shown later, the corn in the various vessels at the time of loading varied considerably in the factors of quality and condition. Likewise, a large proportion of the corn became hot and damaged while it was in the vessels. The records show that the quality and condition of the corn at the time of loading, the position of stowage in the vessel, the length of the voyage, the season of the year during which the corn was shipped, and the weather conditions during the voyage, each influenced, to a great extent, the carrying qualities of the corn during the time it was in the vessels.

MOISTURE CONTENT AS A FACTOR INFLUENCING THE CARRYING QUALITIES OF EXPORT CORN.

The moisture content of corn, and of other grains as well, is the primary factor determining their capacity to carry safely in ocean transit without deterioration. Corn in which the moisture content is sufficiently low will carry safely under ordinary conditions of ocean transit for any reasonable length of time during any season of the year, no matter where it is stowed in the vessel, while corn containing a high moisture content is constantly in danger of heating at any time owing to a variety of contributing causes. Thoroughly air-dried corn contains from about 12 to 13 per cent of moisture. Such corn may be shipped for export at any time under ordinary conditions with little or no danger from heating in transit, and this is practically true also of corn containing up to 14 per cent moisture provided fermentation has not started. The fact that certain lots of corn contain higher percentages of moisture does not necessarily mean that they will not stand ocean shipment safely. The corn may be perfectly sound, the voyage may be short, the air temperature at the time of loading and during the voyage may be low, no disturbing influence such as heat radiating from the ship's boilers and engine rooms and shaft tunnels may be encountered, and the corn kept practically in cold storage. Under such most favorable conditions, corn with a relatively high moisture content may sometimes be safely carried. Cargoes of such corn are often landed upon the quays in Europe in a perfectly cool condition, which corn, upon being exposed to warm atmospheric conditions often becomes hot and unfit for reshipment in a short time. When corn "goes out of condition" the effect of its relative moisture content immediately becomes evident. Corn with a low moisture content requires a much longer time to reach that stage designated as "hot" or to become discolored or "damaged" by the process of heating, than corn with a high moisture content, while corn with a high moisture content will heat, become discolored, and lose weight by evaporation quickly, and the processes of deterioration are accelerated with each additional per cent of moisture much more rapidly than the proportionate increase in the moisture content. When corn of a low moisture content is found in a heating condition, it can ordinarily be restored to a cool condition with but a slight amount of handling and ventilating and without much, if any, loss in value through discoloration, while corn with a high moisture content, when heated in any considerable bulk, quickly becomes badly discolored and damaged and is restored to a cool condition with great difficulty and a great amount of handling only with more or less damage to its quality and a corresponding loss in value.

It will be noted from the following charts and tables that many of the samples showed a higher moisture content at the time of discharge in Europe than the corn had at the time of loading. It is not thought possible under ordinary conditions of ocean transportation for corn or other grain, confined as it is in the holds of ships, to take on moisture from the air, as grain from semiarid regions is said to do when otherwise transported to more humid regions. This is especially true when the moisture content of the corn as shipped is high. There are two means by which the moisture content in any part or the whole of the ship's corn cargo may be increased during transportation: (1) Transfer of moisture by air currents caused by changes in temperature, and (2) by chemical changes within the corn kernel. As to the first means, corn containing excessive moisture and situated so that the moisture can escape when subjected to heat, will give off moisture and become drier. The moisture thus given off in a ship's hold, in case the temperatures in the hold are not uniform, finds its way to the usual air space above the corn and under the deck, passing thence as water to other parts of the hold where it condenses on the cooler corn, the cooler deck, and the sides of the ship. This process, augmented as time goes on by the second means, may increase considerably the moisture content of the corn in some portions of the hold or cargo.

The second means by which the moisture content of the corn may be increased is by the change in the chemical composition of the kernel, the effect of which is more evident in corn that is heating badly. Conditions of temperature and moisture may be favorable in some part of the cargo for fermentation to begin and to continue with more or less vigor. The heat generated in this process is gradually transmitted to the surrounding portions, starting and increasing fermentation, which decomposes the grain and liberates its water of composition, thus increasing the amount of moisture in some portions or in the whole cargo, if conditions are not disturbed, without any addition whatever of moisture from outside sources. From these causes, the grain in many of the shipments examined was found to be damp and heating at the top, while that beneath was cool, and the iron decks and sides of the ship were found to be quite wet from the condensed moisture from the heating corn.

GERMINATION AND FERMENTATION IN EXPORT CORN.

In the grain trade the germinating season, so called, is said to be a special season in the year during which grain is customarily planted in the ground. The limits of this season are generally understood to extend from the middle of March to the middle of June. It is generally believed that there is a natural and inherent tendency in grain to germinate during that season and that the heating of grain in storage and in transit during those months is due primarily to this tendency. Sprouted corn was occasionally found in the cargoes examined, but only at the top of the bulk, where considerable additional moisture had been supplied, either through condensation as described elsewhere or from outside sources, and where the corn had access to fresh air. In order that corn, or any of the grains, may germinate, there must be present: (1) Air or ogygen, (2) heat, and (3) moisture. If one or more of these are absent, germination will not take place, but if all are present at the same time and in sufficient quantities and the germ of the corn be alive, germination will take place, regardless of the time, the place, or the season of the year. There can be no doubt that the same conditions of temperature and moisture that favor germination or the active growth of the germ of the grain, are favorable also to the growth of molds and bacteria as well as the production and action of certain ferments and enzymes which have the power of changing the composition of the grain kernels and which in their action produce heat sufficient to cause the heating of the grain. Fermentation is the principal danger to which damp grain in storage or in transit is exposed. Corn in which fermentation has begun need not necessarily be hot or even perceptibly heating, but the action is usually indicated by a peculiar, faintly sour odor present. The presence of this odor should serve as a warning to the shipper or handler of grain, because corn in which the odor is present soon becomes hot if not frequently and thoroughly ventilated, especially if its moisture content is high. The process of fermentation develops acid within the corn kernel, and the degree to which fermentation has taken place in any given lot of corn may be very closely determined by the acidity test and is expressed in this publication in terms of "acidity c. c." The maximum limit of acidity allowed by Australian and Italian law in corn to be consumed for human food is 30 c. c. and this is also the maximum limit allowed by the pure food board of South Carolina in corn entering that State. Corn testing over 30 c. c. in acidity is such that no reputable grain man in this country would class it in any of the numerical grades. In several hundred samples of corn tested by the department, corn on the farms averaged 18.1 c. c., corn received at terminal markets 20.4 c. c.,[1] and the corn discharged at foreign ports averaged 30.4 c. c. in acidity. It will be of interest to note that of these samples, those taken from the farm tested 76.5 per cent in germination, samples received at terminal markets tested 58.8 per cent in germination, and samples taken at foreign ports tested 31 per cent in germination, showing that there is a close relation between the soundness of corn as determined by the acidity test and its viability.[2]

THE KEEPING QUALITIES OF EXPORT CORN INFLUENCED BY ITS POSITION OF STOWAGE IN THE STEAMSHIP.

Practically all of the corn that is exported to Europe from the United States is carried in bulk, with the exception of small quantities placed in sacks, which are used for trimming the cargo in order to prevent the bulk grain from shifting with the rolling and pitching of the ship. When the corn is thoroughly air-dried, it is not a matter of great importance where or how it is stowed, as long as it does not come in contact with the sea water, green or wet shifting boards, or damp or wet freight or wet lumber, etc. Where the shipments of corn contained a percentage of moisture much above that of thoroughly air-dried corn, it was found that at least some of the corn was often in a heating condition at the time of discharge. Where the heating occurred in positions of stowage free from the engine and boiler-room bulkheads and the shaft tunnels, the greatest heat and the most severe damage were found at the surface, the less heat and the less degree of damage the farther the distance down in the hold. When the damaged corn was located in that section of the ship contiguous to the boiler and engine-room bulkheads or to the propeller shaft tunnels, the greatest heat and the most severe damage were found nearest to those bulkheads and shaft tunnels, and the less heat and less degree of damage the farther the distance from them. The usual situation in such cases is clearly indicated in figures 17 and 54.

LENGTH OF THE VOYAGE AND SEASON OF THE YEAR WHEN SHIPPED, IN RELATION TO THE CARRYING QUALITIES OF CORN.

It appears from these investigations that if the corn when loaded in the ships is sound and dry, the length of the voyage has little or no effect on its condition, but when it is shipped with a high moisture content and is stowed in such a way as to be subjected to heat from the inside of the ship, or is shipped during warm seasons of the year when it is subjected to considerable heat from the atmosphere and water, the length of the voyage is a very important factor, especially if the heating begins early in the voyage, in which case the heat is gradually diffused with each succeeding day and a higher temperature by action of ferments and enzymes, is developed in the corn already hot. Thus, with each succeeding day, more of the sound corn begins to heat and the corn already heating becomes more severely damaged.

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[1] The method of determining the acidity of corn is given in Department of Agriculture, Bulletin 102, entitled "Acidity as a factor in determining the degree of soundness of corn."

[2] The germination tests given in this report were made by the Seed Laboratory of the Department of Agriculture.

CARGO No. 1.

Cargo No. 1 consisted of 240,000 bushels of corn, which was discharged at three ports in Denmark. The grain was loaded on the 6th, 7th, and 8th of March, 1910. The vessel sailed on the 8th of March and arrived at Copenhagen April 1, where the discharge of the corn was begun on April 4. The last of the corn in the vessel was discharged at Aalborg on April 15. The length of the voyage to Copenhagen was 24 days. The average time the corn was in the vessel was 34 days and the maximum time 41 days.

DESCRIPTION OF THE CORN.

The cargo contained four lots of corn, each of which was quite distinct in quality and condition from the others. For the purpose of designating these lots in the following pages, they will be called natural "Southwestern," natural "Central," dried "A," and dried "B" corn. Although the origin of each lot could not be definitely determined, the most reliable data available show that the corn designated as natural "Southwestern" was grown in the southwestern part of the corn belt, presumably in Texas and Oklahoma; that designated as natural "Central" originated in the central part of the corn belt, probably chiefly in Illinois; the lots designated as dried "A" and dried "B" were from the same section as the natural "Central" corn, but had been artificially dried.

STOWAGE OF THE CORN.

As is shown in figure 1, each cargo hold of the vessel was filled with corn, except hold 1, which had an air space on the top of the corn of about 4 feet on the port side and of about 6 feet on the starboard side of the shifting boards. Holds 1 and 2 contained only natural "Central" corn. Hold 3 contained both natural "Central" and natural "Southwestern" corn. The natural "Southwestern" corn, amounting to about 6,000 bushels, was stowed near the central part of the hold under the middle and after hatches, and the natural "Central "corn was stowed both immediately above and below the natural "Southwestern" corn. Hold 4 contained natural "Central" and the two lots of artificially dried corn, the natural "Central" being stowed in the upper part of the hold directly under the forward hatch, and separated from the dried corn by wooden staves and a tarpaulin. The dried "A" corn was the upper portion of the dried corn under the two forward hatches of hold 4, and the dried "B" corn filled the remainder of the hold.

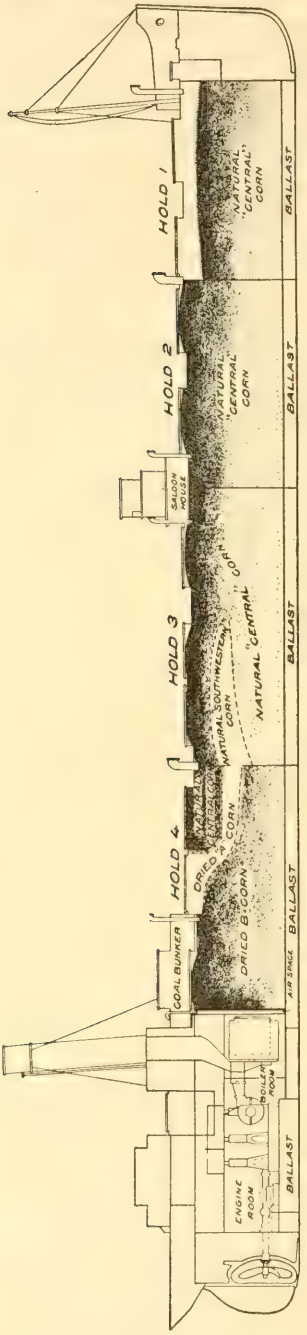


FIG. 1.—Diagram showing the arrangement of the steamship and the stowage of the four lots of corn in the holds. The heavy shading represents heat-damaged corn as discharged.

CONDITION OF THE CORN AS LOADED.

The ranges in the more important factors, showing the quality and condition of the four lots of corn as loaded and as discharged, are shown by holds in Table 1, while the detailed analyses of the samples taken from each lot of corn are shown in Table 2. From these two tables it will be seen that there was a marked difference in the quality and condition of the four lots of corn at the time of loading, each lot considered separately, however, being quite uniform throughout. The average condition of each of the four lots of corn as loaded is shown in Table 3. As seen in Table 3, the natural "Central" corn contained the most moisture, the average being 18.7 per cent. The natural "Southwestern" and the dried "A" corn were both relatively low in moisture content, the averages for these being 14.7 per cent and 14.9 per cent, respectively, while the dried "B" corn averaged 16.3 per cent. The average germination was the highest in the natural "Southwestern" corn, 84 per cent, and the lowest in the dried "B" corn, 32 per cent. The averages for the natural "Central" and the dried "A" corn were 51 per cent and 50 per cent, respectively. The dried "B" corn contained the highest degree of acidity, the average being 27.5 c. c., and the dried "A" corn contained the lowest, the average of which was only 22.5 c. c. The average acidity for the natural "Southwestern" and the natural "Central" corn was 25.8 and 26.6 c. c., respectively.

TABLE 1.—*Range in the principal factors showing quality and condition of the corn in cargo No. 1, as loaded and as discharged by holds.*

Holds.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° *F.*	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold No. 1:						
Natural "Central" corn—						
As loaded	53– 59	18.4–19.3	21.0– 28.5	45–72	85.2–98.7	50.5–53.0
As discharged	60–143	17.5–23.1	24.0–101.0	0–80	0–90.1	45.5–55.3
Hold No. 2:						
Natural "Central" corn—						
As loaded	50– 58	18.6–19.9	21.0– 32.0	28–66	90.6–96.4	51.5–53.5
As discharged	67–140	18.6–20.2	25.5– 52.0	0–79	0–94.6	47.0–53.8
Hold No. 3:						
Natural "Central" corn—						
As loaded	50– 63	17.6–19.2	22.0– 30.0	35–62	91.7–97.2	52.0–54.0
As discharged	55–136	18.8–25.8	25.5– 79.0	0–77	0–89.8	42.5–52.0
Natural "Southwestern" corn—						
As loaded	59– 59	13.9–15.1	22.5– 30.0	77–88	94.6–98.9	52.5–53.5
As discharged	68– 94	14.9–16.4	23.5– 26.5	49–82	96.3–97.8	52.5–52.5
Hold No. 4:						
Natural "Central" corn—						
As loaded	59– 59	18.8–18.8	28.0– 28.0	56–56	95.9–95.9	53.5–53.5
As discharged	144–148	17.8–46.2	38.5– 60.5	0– 0	0– 0	48.5–48.5
Dried "A" corn—						
As loaded	62– 62	14.9–14.9	22.0– 23.0	49–51	96.7–97.4	53.5–54.0
As discharged	79– 80	15.7–17.1	27.0– 28.0	36–59	90.6–94.1	51.0–51.5
Dried "B" corn—						
As loaded	62– 67	15.8–17.2	23.0– 32.0	22–45	77.6–94.1	50.0–53.5
As discharged	74–144	14.5–25.1	27.5– 49.0	0–25	0–88.9	48.5–52.8

Considering all the factors for each lot of corn, it is seen, as far as the three factors of moisture, acidity, and germination are concerned, that the natural "Central" and dried "B" lots were both poor in quality and condition when loaded. The natural "Southwestern" and the dried "A" corn were both in good condition, having a low moisture content, and were likewise better than either of the other two lots in the factors of acidity, germination, sound kernels, and weight per bushel.

As brought out somewhat in detail in the following discussion, there was a close relation between the soundness and condition of the corn at the time of loading and its behavior during the voyage.

TABLE 2.—*Condition of the natural "Central," natural "Southwestern," dried "A," and dried "B" corn as loaded.*

Hold.	Sample No.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
		° *F.*	*Per ct.*	*c. c.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pounds.*
Hold 1, natural "Central" corn	1	53–59	18.5	24.0	56	94.2	1.1	5.1	52.5
	2		18.5	25.0	59	95.6	.6	3.0	52.0
	3		18.8	21.0	....	98.7	.0	3.0	52.0
	4		18.6	25.0	72	96.2	.3	3.6	52.0
	5		18.5	28.5	67	96.3	.2	2.9	53.0
	6		18.5	26.5	60	90.6	.4	2.9	52.5
	7		18.4	25.0	66	96.1	.8	3.2	53.0
	8		19.3	26.5	45	85.2	.5	3.5	50.5

TABLE 2.—*Condition of the natural "Central," natural "Southwestern," dried "A," and dried "B" corn as loaded*—Continued.

Hold.	Sample No.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
		° F.	*Per ct.*	*c. c.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pounds.*
Hold 2, natural "Central" corn	9	50–58	19.1	28.5	....	90.6	.3	3.1	52.0
	10		19.5	32.0	28	92.0	.5	2.7	51.5
	11		18.6	25.5	37	95.4	.5	2.5	52.5
	12		19.2	21.0	43	95.6	.4	3.1	52.0
	13		18.9	28.5	36	95.5	.5	3.0	....
	14		18.8	27.5	47	93.5	.1	2.4	....
	15		18.6	27.0	57	96.4	.4	3.1	53.0
	16		18.7	25.0	66	95.0	.2	2.4	53.0
	17		18.7	26.5	39	92.5	.3	2.8	52.0
	18		18.7	25.5	44	94.4	1.1	4.4	52.0
	19		19.9	26.0	46	92.4	1.5	4.5	52.0
	20		18.6	27.0	48	95.1	.5	5.9	53.0
	21		18.8	26.5	46	94.6	.3	3.1	53.0
	22		18.6	29.5	46	94.2	.5	3.7	53.5
	23		18.7	25.5	56	96.0	1.0	3.6	52.5
Hold 3, natural "Southwestern" corn	24	59	13.9	22.5	88	98.9	.3	4.5	53.0
	25	59	15.1	25.0	87	97.7	.4	7.1	53.5
	26	59	15.0	30.0	77	94.6	3.3	6.9	52.5
Hold 3, natural "Central" corn	27	50–63	18.8	30.0	35	93.6	.7	3.9	52.5
	28		19.2	26.0	52	96.2	.2	1.4	52.5
	29		18.7	27.0	46	91.9	.3	2.3	52.0
	30		18.5	30.0	45	95.8	.3	1.4	52.5
	31		18.5	28.5	39	95.2	.4	3.8	53.0
	32		18.4	25.0	52	97.2	.1	2.6	52.0
	33		18.6	29.5	57	93.8	.3	2.6	52.5
	34		17.6	27.5	49	92.4	.4	2.4	53.0
	35		18.7	22.0	52	96.1	.1	1.6	53.5
	36		18.9	29.0	57	93.3	.2	2.2	53.0
	37		18.5	28.5	55	94.6	.6	5.1	54.0
	38		18.8	28.0	....	94.9	.2	3.8	53.0
	39		19.0	26.5	52	94.1	.3	3.2	53.0
	40		18.0	26.0	62	91.7	.4	1.6	52.5
	41		18.3	....	....	95.0	.4	3.2	52.5
	42		18.6	28.0	50	93.4	.8	3.4	52.0
	43		18.3	24.0	61	96.0	.2	3.0	52.5
	44		18.7	26.5	59	96.8	.3	3.3	52.5
Hold 4, natural "Central" corn	45	59	18.8	28.0	56	95.9	.5	3.2	53.5
Hold 4, dried "A" corn	46	62	14.9	22.0	51	96.7	.2	3.1	53.5
	47	....	14.9	23.0	49	97.4	1.0	6.2	54.0
Hold 4, dried "B" corn	48	62–67	16.1	29.5	22	92.4	.6	4.6	53.5
	49		16.3	27.5	27	90.1	.4	4.4	53.0
	50		16.1	25.5	32	91.2	.4	3.3	53.5
	51		16.3	27.5	38	89.0	1.2	2.7	51.0
	52		16.4	28.0	29	86.6	.5	1.4	52.0
	53		17.2	32.0	45	84.4	12.6	9.4	50.0
	54		16.8	25.0	37	90.7	.7	2.7	53.0
	55		15.9	28.5	35	91.3	1.2	8.0	53.0
	56		15.8	23.0	31	77.6	16.0	20.2	53.0
	57		16.4	28.0	22	94.1	.6	5.0	52.5

TABLE 3.—*Average condition of the four lots of corn as loaded.*

Kind of corn.	Hold No.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
		° F.	*Per ct.*	*c. c.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pounds.*
Natural "Central"	1	56	18.6	25.2	61	94.1	0.5	3.4	52.2
	2	55	18.9	26.8	46	94.2	.5	3.4	52.4
	3	55	18.6	27.2	51	94.6	.3	2.8	52.7
	4	59	18.8	28.0	56	95.9	.5	3.2	53.5
Total natural "Central"	......	55	18.7	26.6	51	94.4	.4	3.1	52.5
Natural "Southwestern"	3	59	14.7	25.8	84	97.0	1.3	6.2	53.0
Dried "A"	4	62	14.9	22.5	50	97.0	.6	4.6	53.5
Dried "B"	4	64	16.3	27.5	32	88.7	3.4	6.2	52.5

TEMPERATURE CHANGES DURING THE VOYAGE.

The first readings of the resistance thermometers were made on March 8, just after the ship left the dock at the beginning of the voyage. With the exception of a few stormy days, readings were made for 25 days thereafter, or until April 2, the day after the ship arrived at Copenhagen. The manner of reading the temperatures of the electrical resistance thermometers is illustrated in figure 2. The temperature of the corn at the time of loading varied from 50° to 67° Fahrenheit. During the voyage much of the corn became very hot. The changes in the temperature of the corn varied considerably in the different positions of stowage and were influenced by the quality, condition, and temperature of the corn when loaded, the boiler heat, the air and water temperatures, and the position of stowage in the ship with reference to height from the bottom of the holds.

The air and water were generally of about the same temperature, save during the latter part of the voyage, when the air was usually colder than the water. The water temperature varied considerably at different stages of the voyage, depending on whether the ship was in harbor, the Gulf Stream, the arctic current, or in the North Sea.

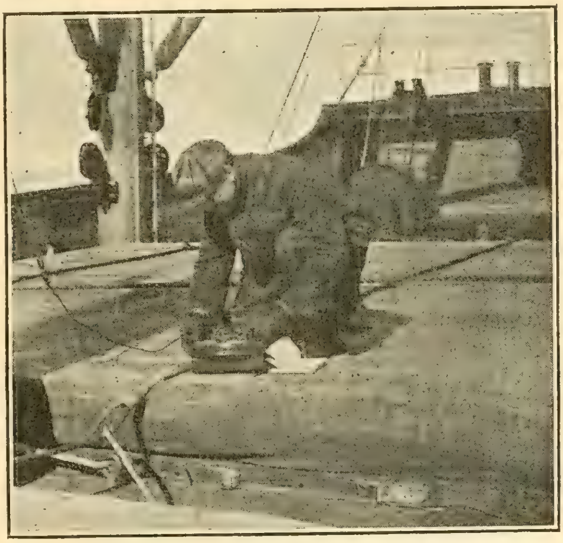


FIG. 2.—Reading the temperature of an electrical resistance thermometer during the voyage.

INFLUENCE OF WATER TEMPERATURE.

The outside walls of the ship consisted of plates of steel, against which the outside layers of the corn rested without any protection. Steel being a good conductor of heat, the temperature of the corn stowed contiguous to these walls was nearly the same as that of the water, as is shown by the temperature records of thermometer 17, figure 5, and thermometer 31, figure 8. The temperature of the corn located a little further in was less affected, as is shown by the temperature records of thermometer 4, figure 3, thermometer 7, figure 4, and thermometer 29, figure 6. The influence of the water temperature gradually decreased with the distance from the sides. The same relation existed with reference to the temperature of the corn located in the bottom of the holds, but not to the same extent as along the sides because of the air space in the ballast tanks and also because the bottoms of the holds were covered by a wooden flooring.

TABLE 4.—*Condition of the natural "Central," natural "Southwestern," dried "A," and dried "B" corn as discharged in Denmark—samples taken in order in the holds from top to bottom.*

Hold.	Sample No.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
		°*F.*	*Per ct.*	*c. c.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pounds.*
Hold 1, natural "Central" corn	58	143	....	49.0	1	0	0.1	1.6	....
	59	138	23.1	101.0	0	0	.3	1.4	....
	60	140	17.6	46.0	0	0	.7	4.3	....
	61	140	17.5	50.0	0	0	1.8	4.1	45.50
	62	132	....	38.0	10	54.7	.2	5.1	48.00
	63	130	17.9	43.0	1	10.2	.6	5.7	47.25
	64	....	19.3	28.5	18	89.7	.4	2.6	49.00
	65	130	19.2	43.5	0	25.4	.4	3.6	47.00
	66	100	19.5	28.0	49	85.3	.4	2.9	50.75
	67	75	19.4	25.5	54	65.4	3.0	6.5	50.75
	68	112	18.5	25.5	57	59.4	.4	4.7	49.00
	69	92	19.7	27.0	53	82.2	2.8	10.2	51.25
	70	....	17.8	35.0	0	0	.2	3.5	....
	71	....	18.8	24.0	65	80.2	.5	2.0	52.00
	72	65	19.2	24.0	80	66.4	1.9	3.7	53.00
	73	67	19.2	26.0	70	72.0	.6	5.9	55.25
	74	60	19.2	27.5	66	90.1	.7	5.7	52.00
Hold 2, natural "Central" corn	75	140	19.7	43.5	0	0	.2	2.8	47.75
	76	134	19.8	52.0	0	0	.9	3.5	47.00
	77	110	20.2	31.0	1	83.7	.5	2.8	....
	78	89	....	27.0	23	88.0	.1	1.7	....
	79	113	18.6	31.5	30	81.6	.6	3.6	50.00
	80	87	19.2	34.5	8	63.0	.2	4.2	....
	81	77	19.2	....	....	....	....	....	51.75
	82	67	19.1	28.0	50	73.3	.8	7.6	51.25
	83	....	19.0	27.0	77	94.6	.5	7.0	53.75
	84	67	19.5	29.0	60	87.4	.2	5.7	51.25
	85	....	19.4	25.5	79	91.4	.2	5.3	53.00
Hold 3, natural "Southwestern" corn	86	94	14.9	26.5	49	96.6	.2	6.0	....
	87	73	15.9	23.5	79	96.3	1.7	5.4	52.50
	88	68	16.4	24.0	82	97.8	.6	4.7	....
Hold 3, natural "Central" corn	89	....	20.1	32.5	28	43.2	.7	2.7	48.50
	90	136	18.9	48.0	0	0	.5	3.1	46.50
	91	130	25.8	79.0	1	0	.5	2.1	42.50
	92	130	19.2	40.5	0	0	.1	2.6	46.00
	93	130	20.3	42.0	0	0	1.3	2.8	44.50
	94	129	18.8	42.0	0	0	.1	3.9	....
	95	119	19.1	38.0	0	83.4	.1	2.0	....
	96	124	19.0	45.0	0	0	.4	1.4	....
	97	118	19.1	35.0	0	69.7	1.0	2.6	....
	98	76	20.1	33.0	31	44.7	.1	3.7	....
	99	95	18.9	41.5	0	0	1.8	4.4	....
	100	72	19.8	25.5	77	79.5	.5	5.2	50.00
	101	81	20.0	30.0	43	87.8	.2	4.7	51.50
	102	67	20.2	26.5	52	89.8	.1	3.7	....
	103	55	19.5	27.0	63	87.1	.2	3.9	51.75
	104	55	19.0	27.0	73	68.5	1.0	4.2	52.00
	105	70	19.5	26.0	64	75.8	.2	3.0	51.50
	106	67	18.9	28.0	63	68.4	.2	2.1	....
Hold 4, natural "Central" corn	107	144	17.8	38.5	0	0	.3	4.8	48.50
	108	148	46.2	60.5	0	0	0	....	....
Hold 4, dried "A" corn	109	80	17.1	27.0	36	94.1	.2	5.2	51.50
	110	79	15.7	28.5	59	90.6	1.6	10.2	51.00
Hold 4, dried "B" corn	111	144	25.1	49.0	0	0	.7	5.7	....
	112	142	16.9	43.0	0	0	1.6	5.5	....
	113	125	14.5	39.0	0	0	.6	5.2	51.75
	114	136	14.5	39.0	2	0	2.0	9.6	51.75
	115	135	15.9	53.0	0	0	.3	6.5	49.50
	116	90	15.2	34.5	21	45.0	.4	5.7	51.75
	117	124	....	48.0	0	0	.6	6.0	50.50
	118	125	16.6	43.5	0	0	.7	3.2	49.00
	119	129	16.9	33.0	2	0	3.5	7.9	51.50
	120	90	15.2	34.5	0	63.9	.3	5.6	48.50
	121	110	15.5	40.5	0	0	.2	3.7	48.50
	122	120	15.2	44.0	0	0	1.2	....	50.50
	123	110	17.1	34.0	0	56.1	2.2	7.9	52.75
	124	89	16.8	32.5	24	88.9	.2	5.7	50.50
	125	80	15.5	34.5	24	82.1	.6	4.6	50.00
	126	74	15.3	27.5	25	76.2	.2	1.7	51.50
	127	114	....	35.0	0	0	.9	3.4	48.75

TEMPERATURE CHANGES IN TOP AND BOTTOM OF HOLDS.

With reference to the temperature changes in the corn located in the upper part of the holds as compared to the temperature changes in the corn in the middle and bottom parts, it will be seen in figures 3 to 6 and Tables 7 and 8, that the corn in the upper part of the holds began to heat first and had the highest temperatures at the end of the voyage. The corn just below the top layers was the next to begin to heat and had the next highest temperature at the end of the voyage.

This order held true with considerable regularity through to the corn in the bottom portion of the holds, although not to such a great extent where there were outside influences, such as the temperature of the sea water, which affected the corn stowed near the sides of the ship, and the heat from the boilers, which was transmitted through the boiler-room bulkhead.

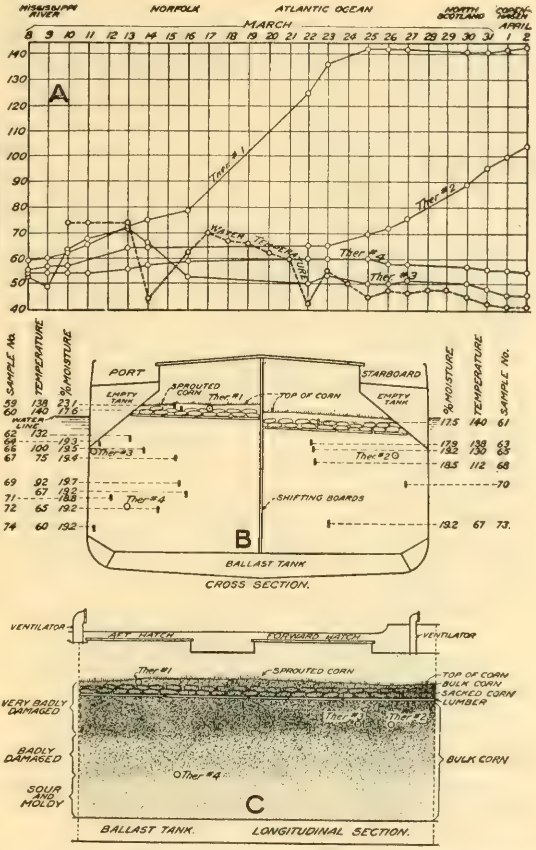


FIG. 3.—Hold 1: *A*, temperature records of the electrical resistance thermometers; *B* and *C*, location of the (1) resistance thermometers in the hold; (2) samples secured in Denmark; (3) the damaged corn as discharged in Denmark. (Cargo No. 1.)

Thus, in the natural "Central" corn in hold 1 (thermometer No. 1, fig. 3) the temperature of the corn in the top portion began to increase from the beginning of the voyage and had a temperature of 142.5° F. at the end of the voyage, which was an increase of 83.5° F.; while the corn located about one-third of the distance down in the hold (thermometer No. 2) did not begin to show a rapid daily increase until about the thirteenth day out, and had a temperature of only 103.5° F. at the end of the voyage, an increase of 47.5° F. The corn in the bottom layer had a temperature of only 55° F. at the end of the voyage, as shown by the temperature record for thermometer 4, figure 3. The corn in this position did not become hot and actually showed a lower temperature at the end of the voyage than during the middle of the voyage, because of the influence of the water temperature. The same order prevailed in the natural "Central" corn in the other holds in which it was stowed, although the temperature in each relative position varied somewhat in the various holds. The natural "Southwestern" corn in hold 3 and the dried "A" corn under the forward and middle hatches in hold 4, as is shown by the temperature records for thermometers 11 and 30 in figures 5 and 7, did not become hot during the voyage for reasons explained elsewhere.

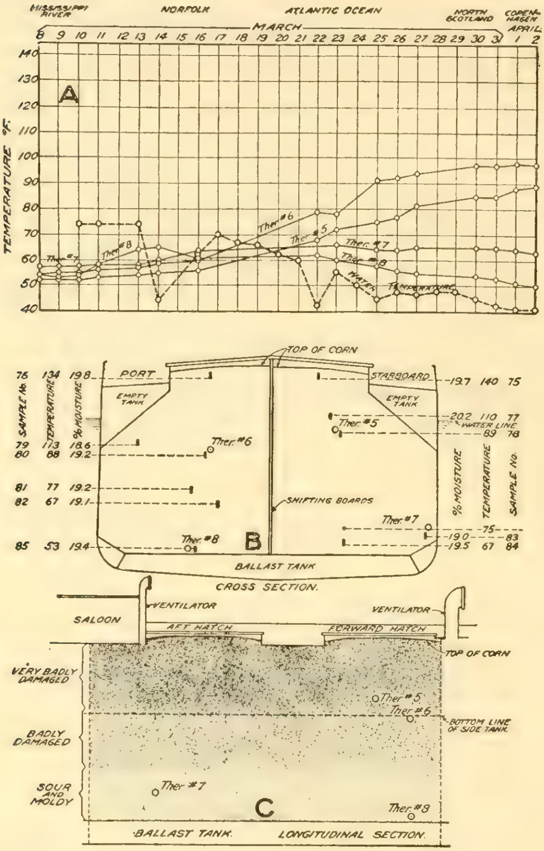


FIG. 4.—Hold 2: *A*, temperature records of the electrical resistance thermometers; *B* and *C*, location of the (1) resistance thermometers in the hold; (2) samples secured in Denmark; (3) the damaged corn as discharged in Denmark. (Cargo No. 1.)

The upper portion of the dried "B" corn immediately under the dried "A" lot in the forward part of hold 4 (sample 115, fig. 6) had a temperature at the end of the voyage of 135° F., as against 113° F. for the corn in the bottom of the hold (thermometer record 23, fig. 7). This same relation held true for the dried "B" corn located under the after hatch, as is shown by the temperature records of thermometers 21, 22, 26, and 29, and also for the corn located against the boiler-room bulkhead, although the latter was affected by the heat from the boilers. The above condition is almost invariably true in all cargoes containing heating corn.

INFLUENCE OF BOILER HEAT.

The heat generated in the boiler room exerted considerable influence on the temperature of the corn stowed contiguous to the boiler-room bulkhead. As hot air always moves upward and cold air downward, this influence would naturally be expected to affect the corn stowed against the upper part of the boiler-room bulkhead more than that which was stowed against the lower part, which proved to be the case in this shipment. That part of the dried "B" corn which was located against the upper part of the boiler-room bulkhead increased in temperature at a much faster rate during the early part of the voyage than the corn in any other position in the ship. The temperature of all the corn stowed along this bulkhead registered under 65° F. at the time of loading. From early morning until 4 o'clock in the afternoon of the day of sailing, March 8, the ship's boilers were under pressure of steam, and considerable heat was generated in the boiler room. In this short time the temperature of the corn located against the upper part of the bulkhead had increased to 76° F., as shown by the temperature record of thermometer 18 in figure 6, while the corn at the same height in the hold, not more than 8 feet away from the bulkhead, was only 62° F., as is shown by temperature record of thermometer 22. Eight days later the corn against the upper part of the boiler-room bulkhead had increased to 102° F., while the temperature of the corn located only 8 feet away was only 65° F. From March 17 to 19, inclusive, the weather was stormy, and no more readings were made until March 20, 12 days after sailing, by which time the temperature of the corn along the upper part of the bulkhead had increased to 118° F., a total increase of over 53° F.,

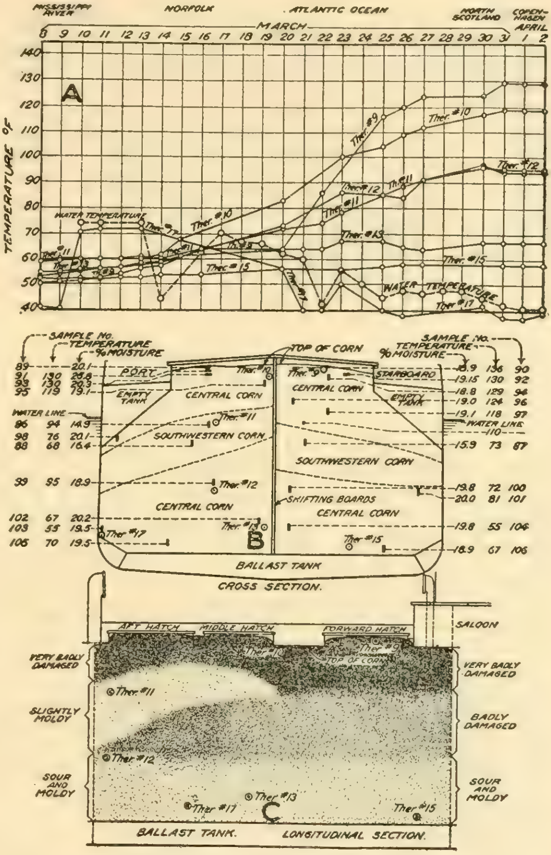


FIG. 5.—Hold 3: *A*, temperature records of the electrical resistance thermometers; *B* and *C*, location of the (1) resistance thermometers in the hold; (2) samples as secured in Denmark; (3) the damaged corn as discharged in Denmark. (Cargo No. 1.)

and the corn stowed 8 feet away from the bulkhead had increased to 80° F., or an increase of only 18° F., but during the next few days the temperature of the corn in the latter position increased very rapidly.

When the ship arrived at Copenhagen on April 1, the temperatures of the corn stowed against the upper, middle, and bottom parts of the boiler-room bulkhead, as is shown by the temperature records for thermometers 18, 24, and 27, were 140°, 118°, and 75° F., respectively, as against 122° and 59° F., for the corn stowed 8 feet from the bulkhead and the same height as the upper and lower positions (there was no record for the middle position) as is shown by the temperature records for thermometers 22 and 29. Note that the corn near the boiler-room bulkhead had a higher temperature by 18° F. in the upper position and by 16° F. in the lower position than the corn located at the same height but 8 feet from the bulkhead.

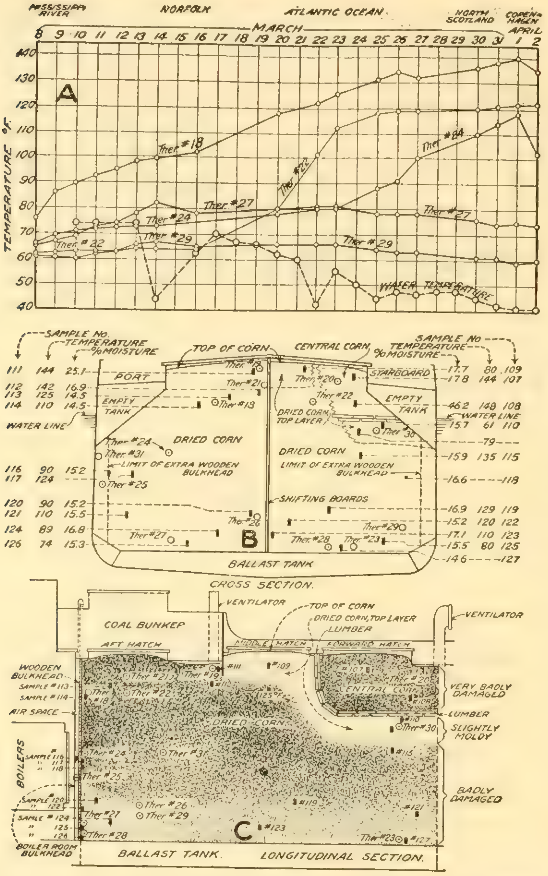


FIG. 6.—Hold 4: *A*, temperature records of the electrical resistance thermometers; *B* and *C*, location of the (1) resistance thermometers in the hold; (2) samples secured in Denmark; (3) the damaged corn as discharged in Denmark. (Cargo No. 1.)

After the ship was docked at Copenhagen, the fires were put out under the main boilers and the effect was quite noticeable on the corn located near the boiler-room bulkhead. The next day, April 2, the temperature of the corn located against the upper part of the bulkhead had decreased 5 degrees as against no decrease for the corn the same height only 8 feet away, the temperatures for these two positions that day being 135° and 122° F., respectively. The temperature of the corn against the middle of the bulkhead (thermometer 24), about half way to the bottom, was 102° F., on April 2, a decrease of 16 degrees from the previous day, and the temperature of the corn against the unprotected part of the boiler-room bulkhead at the extreme side of the hold (thermometer 25) was reduced from 95° F. on April 1 to 82° F. on April 2, a decrease of 13° F. During the voyage the temperature of the corn in the last-named position was affected by both the heat from the boilers and the water temperature.

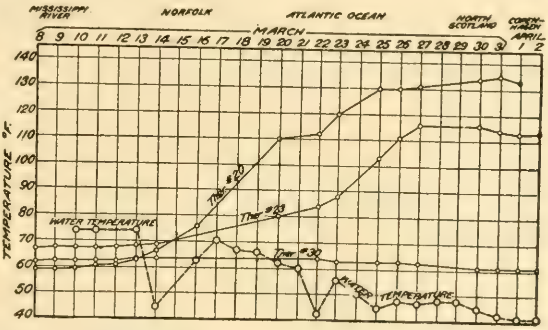


FIG. 7.—Diagram showing temperature records for the corn stowed in the forward part of hold 4.

In connection with the temperatures of the dried "B" corn in hold 4, in the different positions of stowage at the end of the voyage, it is interesting to note at what stage of the voyage the first rapid increase in temperature began. The corn which was stowed next to the upper part of the boiler-room bulkhead (thermometer 18) showed a rapid increase from the beginning of the voyage; next the temperature of the corn in the top layer, immediately under the after ventilator, began to increase rapidly about March 16. At this time in the voyage the ship encountered cold air and the vapor escaping from the heating corn began to condense in the ventilator and fall back on the corn as water. The upper layer of corn a short distance from the boiler-room bulkhead began to increase rapidly in temperature about March 20 and that stowed along the middle part of the boiler-room bulkhead about March 23.

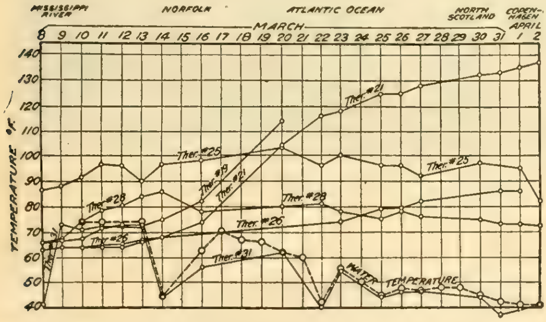


FIG. 8.—Diagram showing temperature records for miscellaneous electrical resistance thermometers in hold 4. (Cargo No. 1.)

CONDITION OF THE CORN AS DISCHARGED.

When the hatches were opened in Denmark, the corn in all of the holds gave off moisture in the form of vapor in great volume, as is illustrated in figure 9, which shows the formation of a dense fog as the result of the warm moisture laden air from hold 4 coming in contact with the cold outside air. When the cargo was discharged it was found that much of the corn had undergone severe deterioration during the voyage.

The detailed analyses of the samples taken from the corn as discharged are shown in Table 4 and the average condition of each lot of corn as discharged is shown in Table 5.

TABLE 5.—*Average condition of the four lots of corn as discharged in Denmark.*

Kind of corn.	Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
		°F.	*Per ct.*	*c. c.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Pounds.*
Natural "Central"	1	96	19.1	35.5	42	54.4	1.0	4.5	50.7
	2	96	19.4	33.5	29	64.0	.4	4.2	50.2
	3	90	19.7	34.6	35	50.9	.5	3.5	49.4
	4	[1] 146	17.8	49.5	0	0	.2	4.8	48.5
Total natural "Central"		[1] 95	19.4	35.0	33	54.0	.6	4.0	49.9
Natural "Southwestern"	3	78	15.7	24.7	70	96.9	.8	5.4	52.5
Total dried "A"	4	80	16.4	27.8	48	92.4	.9	7.7	51.3
Total dried "B"	4	119	[2] 15.7	40.8	4	17.4	.9	5.7	50.8

[1] Sample 108 not included.

[2] Sample 111 not included.

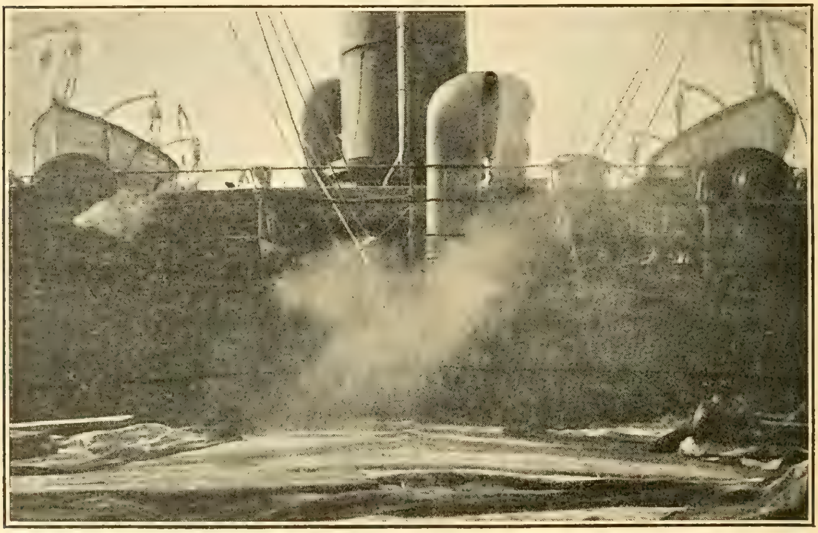


FIG. 9.—Moisture from heating corn escaping from a ventilator and from an open hatch at the end of the voyage. (Cargo No. 1.)

It will be seen from Table 4 that the natural "Central" corn which had an average moisture content of 18.7 per cent and an average acidity of 26.6 c. c. at the time of loading, was badly damaged in the upper part of all holds at the time of discharge. The corn was hot, discolored, very sour, and badly affected with molds. As is shown in figures 3 to 6 and Table 4, the degree of damage, as well as the temperature of the corn, gradually decreased toward the bottom of the holds, where the corn was not discolored, but was noticeably sour and more or less affected with molds. The damaged and packed condition of the corn in the upper part of holds 1 and 2 at time of discharge is illustrated in figure 10. The corn in hold 1 did not entirely fill the hold, and the top of the corn was covered with a heavy growth of sprouted corn, as is shown in figure 12.

The comparison of the average condition of each lot of corn, as loaded and as discharged, is given in Table 6. As shown in this table, the natural "Southwestern" corn in hold 3, which had an average moisture content of 14.7 per cent and an average acidity of 25.8 c. c. when it was loaded, arrived in practically the same condition as when loaded, although the natural "Central" corn stowed both immediately above and below it was hot and damaged and badly packed, as is illustrated in figure 5. The natural "Southwestern" corn "run" freely during the discharge, thus leaving overhanging walls of natural "Central" corn, these overhanging walls at times projecting as much as 2 feet or more.

TABLE 6.—*Comparison of the average condition of the natural "Central," natural "Southwestern," dried "A," and dried "B" corn as loaded, with the average condition of each lot as discharged in Denmark.*

Kind of corn.	Hold.	Condition of corn as—	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
			°F.	*P. ct.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*
Natural "Central"	1	Loaded	56	18.6	25.2	61	94.1	0.5	3.4	52.2
	1	Discharged	96	19.1	35.5	42	54.4	1.0	4.5	50.7
	2	Loaded	55	18.9	26.8	46	94.2	.5	3.4	52.4
	2	Discharged	96	19.4	33.5	29	64.0	.4	4.2	50.2
	3	Loaded	55	18.6	27.2	51	94.6	.3	2.8	52.7
	3	Discharged	90	19.7	34.6	35	50.9	.5	3.5	49.4
	4	Loaded	59	18.8	28.0	56	95.9	.5	3.2	53.5
	4	Discharged	[1] 146	17.8	49.5	0	0	.2	4.8	48.5
Total natural "Central"		Loaded	55	18.7	26.6	51	94.4	.4	3.1	52.5
		Discharged	[1] 95	19.4	35.0	33	54.0	.6	4.0	49.9
Natural "Southwestern"	3	Loaded	59	14.7	25.8	84	97.0	1.3	6.2	53.0
	3	Discharged	78	15.7	24.7	70	96.9	.8	5.4	52.5
Dried "A"	4	Loaded	62	14.9	22.5	50	97.0	.6	4.6	53.5
	4	Discharged	80	16.4	27.8	48	92.4	.9	7.7	51.3
Dried "B"	4	Loaded	64	16.3	27.5	32	88.7	3.4	6.2	52.5
	4	Discharged	119	[2] 15.7	40.8	4	17.4	.9	5.7	50.8

[1] Sample 108 not included.

[2] Sample 111 not included.

Figure 6 and Table 6 show that the dried "A" corn in hold 4, which had an average of 14.9 per cent of moisture and an average acidity of 22.5 c. c. when it was put on board, also arrived in Denmark in practically as sound a condition as when it was loaded, notwithstanding that both the "Central" corn, which was stowed immediately above it, and the dried "B" corn, just beneath it, was hot and badly damaged. Figure 6 and Table 6 also show that the dried "B" corn in hold 4, which had an average moisture content of 16.3 per cent and an average acidity of 27.5 c. c. at the time of loading—the highest acid content of any lot in the shipment—was hot and badly damaged throughout when discharged with the exception of a small quantity along the bottom in the afterpart of the hold, which was not hot but was badly packed, sour, and affected with molds. This dried "B" corn was so badly packed that it formed perpendicular walls from the top to the bottom of the hold (about 20 feet) when it was being discharged, as is illustrated in figure 11.

"SWEAT" AND SPROUTED CORN IN THE HOLDS.

When the cargo arrived in Denmark the top layer of corn in hold 1 was sprouted as is shown in figure 12, the sprouts in many instances measuring 8 inches and more in length. This hold, which was not entirely filled with corn, was, as already stated, the only hold in which there was a free circulation of air from the forward to the after ventilators. This free circulation of outside air over the corn supplied the necessary oxygen and kept the top layers of kernels cool enough through evaporation to germinate. The necessary moisture needed for germination, in addition to the moisture present within the kernels, was supplied by the "sweat" dropping from the deck above. In other holds in which the circulation of air was impeded there was only a very slight amount of sprouted corn, the sprouted kernels being found only under some of the hatch beams. The air was very "heavy" in these holds due to the oxygen having been used up and replaced by carbon dioxide.

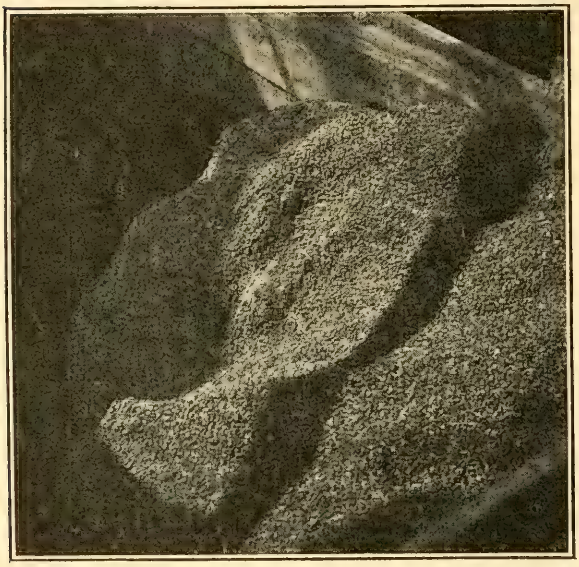


FIG. 10.—Damaged corn in the upper part of hold 2 at time of discharge. (Cargo No. 1.)

What is known as "sweat" in a corn cargo is water that has condensed on the underside of the cooler deck or on the sides of the ship when the temperature on the outside of the hold is lower than the temperature on the inside. This "sweat" on the underside of the deck falls back onto the corn in the form of water, as illustrated in figures 13 and 14. In the rolling and pitching of the ship, most of the "sweat" on the underside of the deck works its way to the deck beams and from there it falls onto the corn where it supplies the necessary moisture for germination or fermentation as the case may be. The sprouted corn immediately under those beams in hold 1 showed a much more vigorous growth than at other places. During the voyage the moisture from the heating corn could be plainly seen escaping from the ventilators and especially from the after ventilators in hold 4, shown in figure 9, where it was first noticed on the sixth day out when cold air was encountered which condensed the excess moisture in the warm air from the hold into fog.

MOISTURE TEST ALONE NOT SUFFICIENT TO DETERMINE CARRYING QUALITY OF CORN.

The moisture test alone is not sufficient to determine the carrying quality of corn, there being other factors which must also be considered. Based on the moisture test alone, the dried "B" corn stowed in the bottom part of hold 4 should have been in better condition at the end of the voyage than the natural "Central" corn in the bottom of holds 1, 2, and 3, which at the time of loading had an average of 2.4 per cent more moisture than the dried "B" corn. The condition at the end of the voyage of these two lots of corn, however, proved to be the reverse, and the explanation of it is that although the dried "B" corn contained on an average less moisture than the natural "Central" corn, the dried "B" corn was less sound as shown by the acidity test. The combination of a comparatively high moisture and high acid content caused the dried "B" corn in the lower part of the hold to become hot during the voyage. As will be seen by thermometer 23 (fig. 7), which was located near the forward bulkhead in the bottom of hold 4, the temperature of the

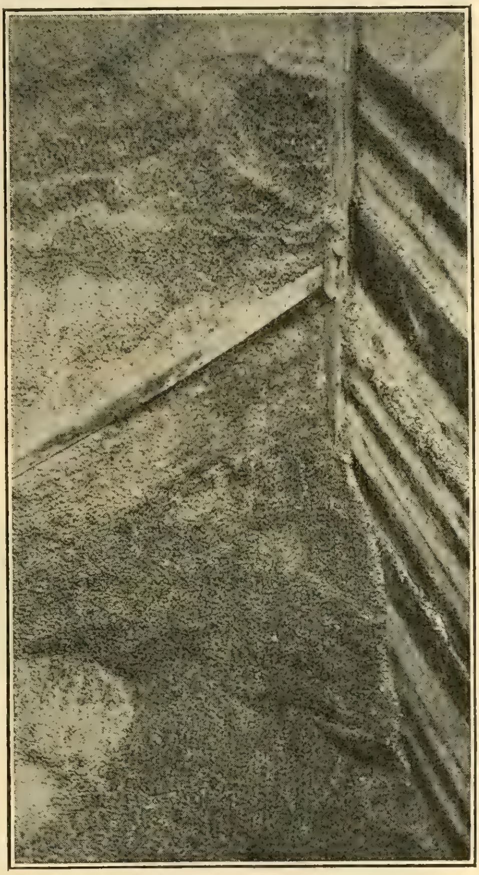


FIG. 11.—Perpendicular wall of hot and damaged dried "B" corn in hold 4 at time of discharge. (Cargo No. 1.)

corn at that point was 113.5° F. at the end of the voyage, as against a temperature of only 67° F. for thermometer 13 (fig. 5), in hold 3 located in the bottom portion of the natural "Central" corn only a short distance from thermometer 23.

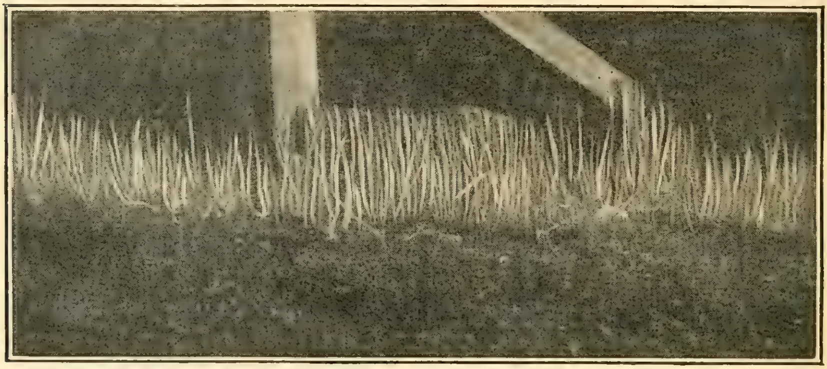


FIG. 12.—Illustrating the sprouted condition of the surface layer of corn in hold 1 when the cargo arrived in Denmark. (Cargo No. 1.)

The difference between the keeping qualities of corn containing a high moisture content and showing a high acid test and of corn in which these two factors are low was illustrated in holds 3 and 4. In hold 3 the natural "Southwestern" corn, which at time of loading was lower on an average by 4 per cent in moisture content and by 0.8 c. c. in acidity than the natural "Central" corn in the same hold, remained sound, while the

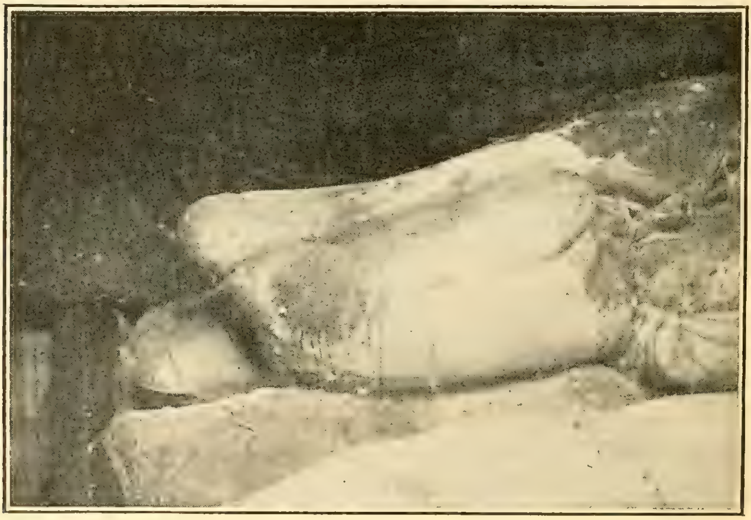


FIG. 13.—Showing where "sweat" had dropped from the underside of the deck onto the bags of corn in the upper part of the hold. (Cargo No. 1.)

natural "Central" corn surrounding it became badly damaged. Also, in hold 4 the dried "A" corn, which at time of loading was lower by 1.4 per cent in moisture and by 5 c. c. in acidity than the dried "B" corn, remained sound, while the dried "B" corn in the same relative position of stowage as the dried "A" corn became badly damaged.

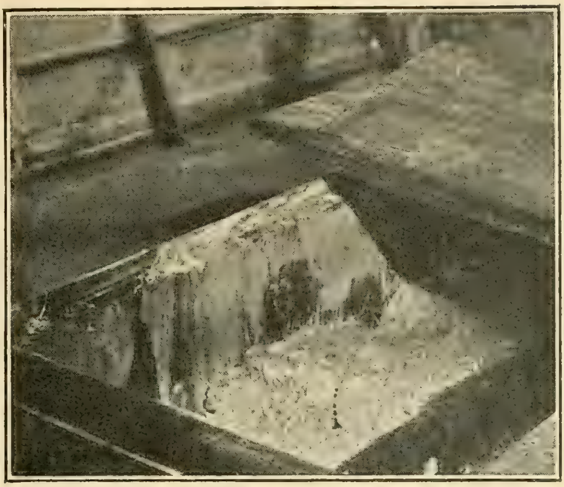


FIG. 14.—Illustrating the results of "sweat" on the top portion of the corn under the hatch in hold 3. (Cargo No. 1.)

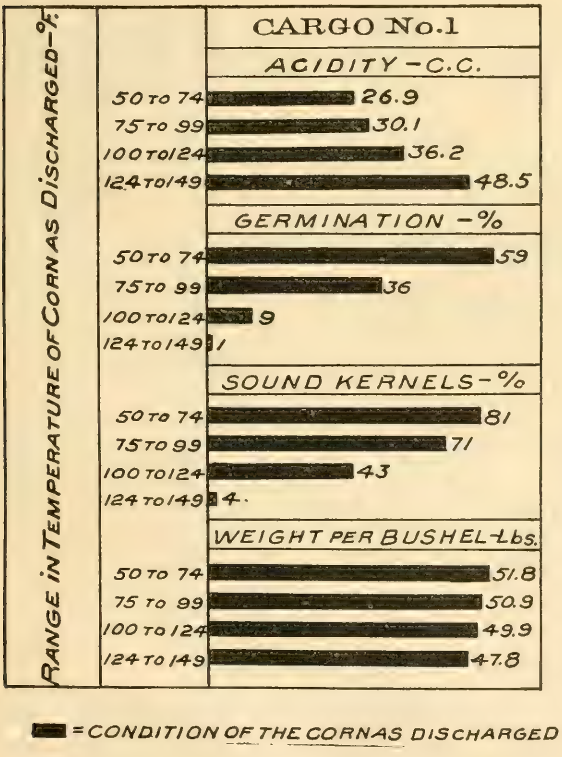


FIG. 15.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 1.)

CORRELATION OF THE CHANGES IN TEMPERATURE AND THE CHANGES IN ACIDITY, GERMINATION, MOISTURE CONTENT, AND TEST WEIGHT PER BUSHEL.

The comparison of the average condition of the natural "Central," natural "Southwestern," dried "A" and dried "B" corn in each hold; also the comparison of the averages for the total corn of each lot at the time of loading with the averages at time of discharge in Denmark are shown in Table 6. The average condition of the corn in each lot in the top third, middle third, and bottom third of holds at time of discharge in Denmark is shown in Table 7, and the condition of the individual samples that were put into the crossed wire containers at the time the corn was loaded compared to the condition of each at the time when the corn was being discharged is shown in Table 8. It will be seen from these tables that, with a few unimportant exceptions, there was on an average quite a noticeable change in the acid content, germination, percentage of sound kernels, and weight per bushel during the voyage corresponding quite closely with the changes in the temperature in each lot of corn and in each position of stowage. As is seen from Table 6, the acidity was generally greater, while the weight per bushel and percentages of germination and sound kernels were generally less at the end of the voyage than at the beginning, the greatest differences being apparent in most cases in the corn which had increased the most in temperature, as is shown in figure 15.

TABLE 7.—*Average condition of each lot of corn in the top third, middle third, and bottom third of holds as discharged in Denmark.*

Kind of corn.	Place of stowage in hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Badly broken kernels.	Weight per bushel.
Natural "Central" corn:		°F.	*P. ct.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*
Hold 1	Upper third	132	19.2	53.4	9	29.5	0.5	3.0	47.9
	Middle third	93	18.8	27.4	46	57.4	1.4	5.4	50.8
	Bottom third	64	19.2	25.8	72	76.2	1.1	5.1	53.4
Hold 2	Upper third	128	19.9	42.2	0	27.9	.5	3.0	47.4
	Middle third	92	19.0	31.0	20	77.5	.3	3.2	50.9
	Bottom third	67	19.3	27.4	67	86.7	.4	6.4	52.3
Hold 3	Upper third	127	20.0	44.6	3	21.8	.5	2.6	45.6
	Middle third	81	19.7	32.4	38	53.0	.7	4.5	50.8
	Bottom third	63	19.4	26.9	63	77.9	.3	3.4	51.8
Hold 4	Upper third	[1] 146	17.8	49.5	0	0	.2	4.8	48.5
Total natural "Central," natural "Southwestern," dried "A," and dried "B" corn:									
Natural "Central"	Upper third	[1] 131	19.6	46.3	3	22.9	.5	3.1	47.0
Dried "A"		80	16.4	27.8	48	92.4	.9	7.7	51.3
Dried "B"		137	[2] 15.3	42.5	0	0	1.2	6.5	51.8
Natural "Central"	Middle third	88	19.2	30.7	34	62.5	.7	4.3	50.8
Dried "B"		119	15.9	44.8	5	11.3	.5	5.4	50.2
Natural "Southwestern"		78	15.7	24.7	70	96.9	.8	5.4	52.5
Natural "Central"	Bottom third	64	19.3	26.8	66	80.5	.5	4.8	52.4
Dried "B"		102	15.9	35.1	8	40.8	1.0	5.1	50.3

[1] Sample 108 not included.

[2] Sample 111 not included.

THE HANDLING OF THE CORN AS DISCHARGED.

Much of the corn was so badly damaged that the marine leg could not be used to discharge it. All of the dried "B" corn in hold 4 on account of its packed condition had to be discharged by use of buckets or bags and winches. Discharging corn with bags or buckets is a slow process and necessitates much extra labor and time, thus allowing any hot corn that the cargo may contain to become more severely damaged and also giving time for the damage in the affected location to spread to the surrounding sound corn.

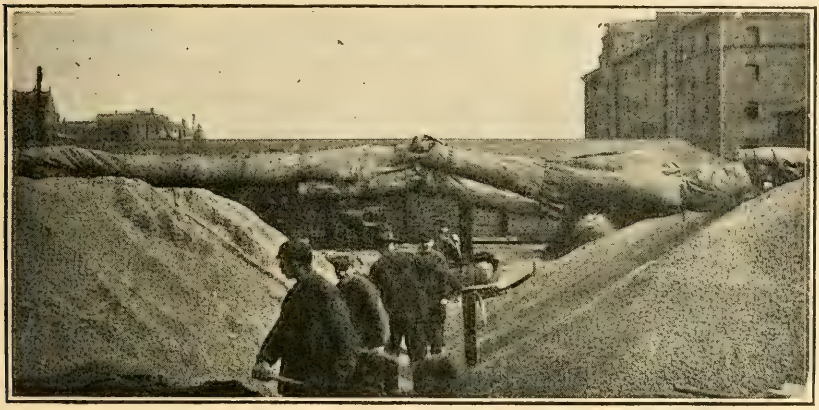


FIG. 16.—Hot corn from the cargo piled on the open quay being conditioned by hand shoveling. (Cargo No. 1.)

TABLE 8.—*Comparison of the condition of the corn samples in crossed-wire containers as loaded and as discharged.*

Kind of corn.	Condition of corn as—	Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Dirt and foreign matter.	Weight per bushel.	Location of sample in hold.
			° F.	*P. ct.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	
Natural "Central".	Loaded.....	1	59	18.5	28.5	67.0	96.3	0.2	53.0	Top.
	Discharged..	1	143	......	49.0	1.0	0	.1	....	
	Loaded.....	1	53	18.8	21.0	......	98.7	0	52.0	5 feet down near outside.
	Discharged..	1	68	19.3	28.5	18.0	89.7	.4	49.0	
	Loaded.....	1	56	18.5	26.5	60.0	90.6	.4	52.5	16 feet down near outside.
	Discharged..	1	104	17.8	35.0	0	0	.2	....	
	Loaded.....	2	50	19.2	21.0	42.5	95.6	.4	52.0	10 feet down.
	Discharged..	2	89	......	27.0	23.0	88.0	.1	....	
	Loaded.....	2	50	18.9	28.5	36.0	95.5	.5	....	13 feet down.
	Discharged..	2	88	19.2	34.5	8.0	63.0	.2	....	
	Loaded.....	3	50	18.7	22.0	52.0	96.1	.1	53.5	Top.
	Discharged..	3	129	18.8	42.0	0	0	.1	....	
	Loaded.....	3	59	18.5	28.5	38.0	95.2	.4	53.0	4 feet down.
	Discharged..	3	119	19.1	38.0	0	83.4	.1	....	
Natural "Southwestern."	Loaded.....	3	59	15.1	25.0	87.0	97.7	.4	53.5	10 feet down.
	Discharged..	3	94	14.9	26.5	49.0	96.6	.2	....	
Natural "Central".	Loaded.....	3	55	18.0	26.0	62.0	91.7	.4	52.5	Bottom.
	Discharged..	3	67	18.9	28.0	63.0	68.4	.2	....	
Dried "B".........	Loaded.....	4	66	15.9	28.5	35.0	91.3	1.2	53.0	Top, under ventilator.
	Discharged..	4	141	25.1	49.0	0	0	.7	....	
Dried "A".........	Loaded.....	4	62	14.9	23.0	49.0	97.4	1.0	54.0	Top.
	Discharged..	4	79	15.7	28.5	59.0	90.6	1.6	51.0	
Dried "B".........	Loaded.....	4	67	16.8	25.0	37.0	90.7	.7	53.0	Bottom.
	Discharged..	4	114	......	35.0	0	0	.9	48.75	

It was necessary to begin treating all of the damaged corn almost immediately after it was discharged from the steamship. Some of the corn from the bottom of the three forward holds which was in fair condition when discharged, "went out of condition" and became hot within a short time after being landed, and this also had to be handled at once. The damaged corn from this cargo was ventilated by hand shoveling, each shovelful being thrown into the air in such a manner that the kernels became separated and fully exposed to the air. Figure 16 shows how a part of the hot corn from this cargo, which was piled on the open quay, was treated to stop the process of fermentation.

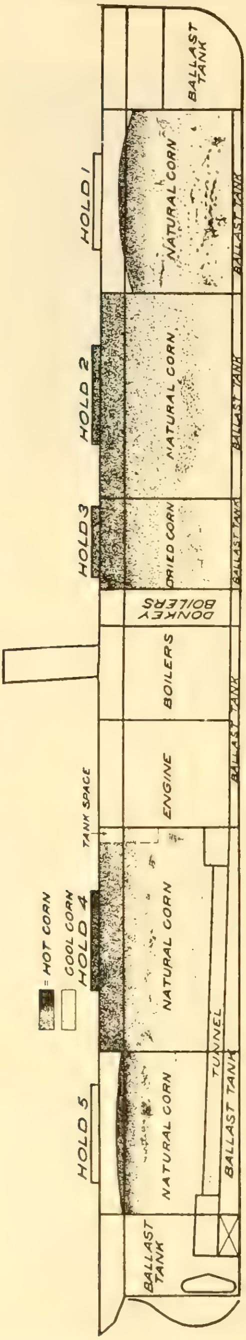


FIG. 17.—Diagram showing arrangement and stowage of the corn in the holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 2.)

CARGO No. 2.

Cargo No. 2 consisted of 211,064 bushels of corn, of which 30,500 bushels had been artificially dried. The corn was loaded February 27, 28, March 1, and 2, 1911. The vessel sailed March 3 and arrived at Aalborg, Denmark, April 5, where 88,827 bushels of the corn were discharged from April 5 to 11. The steamship was then taken to Copenhagen, Denmark, where the remaining 122,237 bushels in the cargo were discharged, the last of the corn being taken out on April 20. The maximum time that any of the corn was in the vessel was 53 days, the average time for the Aalborg lot being 39 days and for the Copenhagen lot 47 days. The length of the ocean voyage to Aalborg was 33 days and to Copenhagen 40 days.

STOWAGE OF THE CORN.

The steamship had five cargo holds. As is shown in figure 17, holds Nos. 2, 3, and 4 were entirely filled with corn, while holds 1 and 5 were each filled only to the main deck, leaving an air space of about 8 feet on top of the corn in the central or "trunk" part of the holds.

The dried corn was stowed in hold 3, and the natural corn in holds 1, 2, 4, and 5.

Holds 1 and 2 were located free from the ship's machinery; hold 3 was located just forward of the boiler room; hold 4 was located just aft of the engine room in the bottom part of which was the shaft tunnel, which also extended through the bottom of hold 5.

TABLE 9.—*Range in the principal factors showing quality and condition of the corn as loaded and as discharged by holds.*

[Holds 1, 2, 4, and 5, natural corn; hold 3, dried corn.]

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° F.	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 1:						
As loaded	51.0- 54.0	18.3-19.2	17.9- 19.9	61.0-77.0	93.1-97.0	52.8-53.5
As discharged	59.0-110.0	16.2-43.6	21.8- 65.7	0-75.0	0-95.6	46.3-54.0
Hold 2:						
As loaded	53.0- 60.0	18.5-18.7	18.7- 19.7	45.0-78.0	94.7-95.6	53.5-53.8
As discharged	58.0-148.0	17.6-34.6	20.8- 75.5	0-78.0	0-96.6	44.0-52.8
Hold 3:						
As loaded	65.0- 74.0	15.2-15.8	20.4- 24.1	34.0-61.0	85.0-96.5	54.0-55.0
As discharged	74.0-155.0	13.0-54.6	23.5-110.8	0-43.0	0-93.7	45.3-54.0
Hold 4:						
As loaded	52.0- 60.0	18.5-19.5	18.5- 24.6	58.0-77.0	92.7-97.5	52.0-54.5
As discharged	59.0-135.0	13.6-48.1	21.1- 83.9	0-69.0	0-96.0	43.3-53.5
Hold 5:						
As loaded	53.0- 55.0	18.3-19.2	19.5- 22.4	62.0-75.0	90.3-95.9	52.5-53.8
As discharged	61.0-140.0	11.1-18.7	23.1- 31.3	0-61.0	0-95.7	47.8-52.0

CONDITION OF THE CORN AS LOADED.

The condition of the natural and dried corn was quite uniform throughout in each lot at the time of loading, as is shown in Table 9, but there was considerable difference in the average condition of the two lots. It will be seen in Table 10 that the averages for various factors in the natural corn as loaded were as follows: Moisture content 18.8 per cent, acidity 19.8 c. c., germination 66.3 per cent, sound kernels 94.7 per cent, and weight per bushel 53.39 pounds; while the averages for the dried corn were: Moisture content 15.5 per cent, acidity 21.9 c. c., germination 43.2 per cent, sound kernels 93.5 per cent, and weight per bushel 54.42 pounds. Comparing the two lots, it is seen that the natural corn was the better in that it had a lower average acidity by 2.1 c. c., a higher average germination by 23.1 per cent, and more sound kernels by 1.2 per cent, but was poorer in that it contained on an average more moisture by 3.3 per cent and a correspondingly lower weight per bushel by a little over one pound.

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

The first temperature readings of the resistance thermometers were made March 1, and thereafter each day that the weather permitted until April 6, the day after the steamship arrived in Denmark. In a few instances the readings were continued until April 15.

TABLE 10.—*Average condition of the corn as loaded compared with the average condition as discharged.*

Kind of corn and hold.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Natural corn:	°*F.*	°*F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
Hold 1	53.0	73.6	18.6	18.3	18.7	25.9	67.2	44.4	95.3	80.8	52.95	51.16
2	56.3	113.5	18.6	18.9	19.4	35.1	62.2	18.1	95.1	23.4	53.56	49.52
4	55.6	95.8	18.9	18.1	20.0	29.8	66.9	25.8	94.6	54.1	53.50	49.93
5	53.8	88.3	18.7	18.2	20.4	26.3	66.8	29.9	94.0	72.9	53.35	50.60
Total natural corn	54.8	94.1	18.8	18.3	19.8	29.4	66.3	28.4	94.7	66.8	53.39	50.20
Dried corn:												
Hold 3	69.6	106.8	15.5	15.1	21.9	31.6	43.2	13.2	93.5	49.6	54.42	51.86

Samples Nos. 43 and 46 in hold 1, 52 in hold 2, 61 in hold 3, and 64 in hold 4, were not included in the average as discharged.

The temperature of the corn as loaded varied from 51° F. in the natural corn to 74° F. in the dried corn, the averages for the two lots in even numbers being 55° and 70° F. At the time of discharge, the maximum temperatures of the corn in the various holds were as follows: Hold 1, 110° F.; hold 2, 148° F.; hold 3, 155° F.; hold 4, 135° F.; and hold 5, 140° F. During the time that the corn was in the vessel a large proportion of both the natural and the dried corn became hot, discolored, moldy, and badly damaged.

When the temperature of corn at 51° and 74° F. is raised through inherent causes, deterioration becomes apparent at about 90 to 100° F. and increases very rapidly thereafter if the temperature continues to rise. The temperature records show that the corn reached 100° F. in the different holds as follows: hold 1 in 35 days, hold 2 in 14 days, hold 3 in 19 days, hold 4 in 22 days, and hold 5 in 24 days. This is interesting in connection with the average time that the corn remained in the vessel, which, as already stated, was 39 days for the Aalborg lot and 47 days for the Copenhagen lot.

The wide difference in the rate at which the temperature of the corn changed depended on its position of stowage with reference to height from the bottom of the holds. Where the corn was stowed free from the ship's machinery, it changed the most and became badly damaged in the upper part of the holds. As is shown by the accompanying diagrams, the temperature and degree of deterioration of the corn at the end of the voyage gradually decreased from the surface toward the bottom where the corn in all holds, excepting that in hold 3 and along the shaft tunnel in holds 4 and 5, was in a sound condition.

The air and water temperatures during the loading period averaged close to 50° F. and were generally somewhat higher than the temperature of the corn for the first six days of the ocean voyage. The air temperature was above 70° F. for the first four days and the water temperature remained above 70° F. for the first six days of the voyage, after which the temperature of both suddenly dropped and remained under 60° F. during the remainder of the voyage. During the latter part of the voyage the air temperature dropped to below 30° F. and the water temperature to nearly 30° F.

CHANGE IN TEMPERATURE AND CONDITION OF THE NATURAL CORN IN HOLD NO. 1.

As is shown in figure 18, the temperature of the corn near the surface on a level with the main deck changed but little during the first 12 days, after which there was a steady daily increase until it had reached 102° F. on April 6, or 35 days after the first reading was made. The upper portion of the corn to a depth of approximately 4 feet below the surface was in a heating condition when the corn was discharged. The remainder of the corn in the hold changed but little in temperature during the voyage.

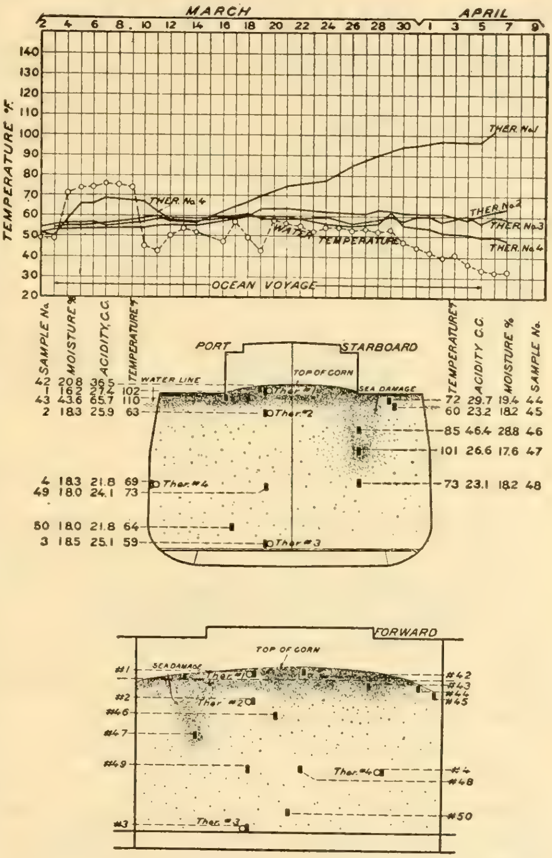


FIG. 18.—Hold 1: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

Sample No. 42 in Table 11, which was taken from the surface of the corn, and sample No. 1, which was taken from the wire container fastened to thermometer No. 1, show the damaged condition of the corn near the surface as discharged. Samples Nos. 43 and 46, which were both badly damaged, represent only a small amount of corn. The first was "sweat"-damaged and the latter sea-damaged from water having leaked through a small hole in the deck.

The average condition of the corn in the hold as discharged is shown in Table 10. Compared to the condition of the corn as loaded, it will be seen from the table that there was an average increase of 7.2 c. c. in acidity and an average decrease of 22.8 per cent in germination; 14.5 per cent in sound kernels and 1.79 pounds in test weight per bushel.

TABLE 11.—*Condition of the natural corn in hold 1 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the hold, from top to bottom.*

[T 1, etc., represents samples in crossed-wire containers, fastened to resistance thermometers of the same numbers; *indicates not included in the averages.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	°F.	*°F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Pounds.*	*Pounds.*
42	......	....	......	20.8	......	36.5	......	5	......	33.4	....	47.25
T 1	54	102	18.8	16.2	17.9	27.4	70	39	97.0	40.4	52.75	50.50
*43	......	*110	......	*43.6	......	*65.7	......	*0	......	*0	....	....
44	......	72	......	19.4	......	29.7	......	13	......	69.9	....	50.00
45	......	60	......	18.2	......	23.2	......	55	......	93.8	....	50.00
T 2	52	63	18.5	18.3	18.9	25.9	77	50	93.1	93.8	52.75	52.00
*46	......	*85	......	*28.8	......	*46.4	......	*3	......	*0	....	*46.25
47	......	101	......	17.6	......	26.6	......	29	......	85.8	....	51.00
48	......	73	......	18.2	......	23.1	......	37	......	92.6	....	51.75
49	54	73	18.3	18.0	19.1	24.1	66	75	94.4	95.2	53.50	53.25
T 4	51	69	18.4	18.3	17.9	21.8	61	54	96.9	94.2	52.75	50.75
50	......	64	......	18.0	......	21.8	......	65	......	95.2	....	54.00
T 3	54	59	19.2	18.5	19.9	25.1	62	67	95.1	95.6	53.00	52.25

CHANGE IN TEMPERATURE AND CONDITION OF THE NATURAL CORN IN HOLD NO. 2.

Fully three-fourths of the corn in hold 2 became hot during the voyage. The greatest increase in the temperature of the corn was at the surface and the lowest at the bottom of the hold. The corn at the surface, when the ship reached port on April 5, was 148° F., that one-third down was 115° F., that two-thirds down 85° F., while that at the bottom of the hold had a temperature of only 50° F. These facts are shown in figure 19.

The temperature of the corn in this hold was under 60° F., in all positions of stowage when loaded. By March 11, 8 days after the steamship sailed, the temperature of the corn near the surface, as is shown by the temperature record for thermometer 5, had increased to 73° F.; during the next 8 days the temperature increased 58° and reached 131° F. on March 19; during the next 10 days to March 29, the increase was more gradual, reaching 149° F. on that day, after which it remained practically stationary until the ship reached port, April 5. The corn located one-third of the distance down, as is seen by the temperature record for thermometer 5, had increased to 68° F. by March 14, and to 118° F. by March 29, which was the maximum point reached before the vessel reached port. The corn located two-thirds of the distance down, as shown by the temperature record for thermometer 7, increased gradually in temperature until 88° F. was reached April 5. Thermometer 8 shows that the temperature of the corn near the bottom did not go over 63° F. and during the latter part of the voyage decreased to 50° F. being influenced by the water temperature.

When the hatch was opened soon after the steamship arrived in Aalborg it was seen that the corn was badly damaged on top. The corn immediately under the hatch was discharged as far down as the main deck, but as there did not appear to be any improvement in the condition, the receivers at this port refused to take any more of it, and consequently the remainder of the corn was left in the hold from about a week to 10 days longer. During this time the temperature of the corn located one-third of the distance down in the hold increased from 115° to 140° F., and the corn stowed two-thirds of the distance down, which was still sound on arrival, increased from 88° to 117° F., and was badly heat discolored when it was discharged. That at the surface had a temperature of over 145° F. for 20 days. As is seen in figure 19, the heat damage finally extended fully three-fourths of the distance down, as the temperature there was 105° F. when the corn was discharged. The grain capacity of this hold was over 73,000 bushels, and as previously stated was entirely filled with corn.

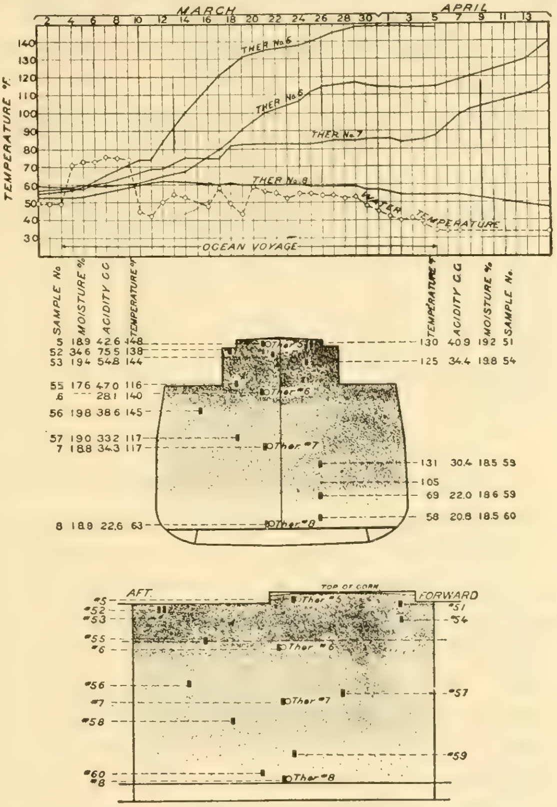


Fig. 19.—Hold 2: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

As is shown in Table 12, only the corn near the bottom of the hold showed any germination or sound kernels at the end of the voyage. Table 10 shows that the averages for the corn in this hold, as discharged, were: Acidity 35.1 c. c., germination 18.1 per cent, sound kernels 23.4 per cent, and weight per bushel 49.52 pounds. This was an increase over the condition, as loaded, of 15.7 c. c. in acidity, and a decrease in even numbers of 44 per cent in germination, 72 per cent in sound kernels, and 4 pounds in weight per bushel.

TABLE 12.—*Condition of the natural corn in hold 2 as loaded and the change in condition while the corn was in the vessel—Samples taken in order in the hold, from top to bottom.*

[T 5, etc., represents samples in crossed-wire containers, fastened to resistance thermometers of the same numbers; * indicates not included in the averages.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	° F.	*° F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Pounds.*	*Pounds.*
T 5	55	148	18.6	18.9	19.7	42.6	64	0	94.7	0	53.50	47.75
51	......	130	......	19.2	......	40.9	......	0	......	0	....	48.25
*52	......	*138	......	*34.6	......	*75.5	......	*0	......	*0	....	*48.00
53	......	144	......	19.4	......	54.8	......	0	......	0	....	44.00
54	......	125	......	19.8	......	34.4	......	0	......	0	....	48.50
55	......	116	......	17.6	......	47.0	......	0	......	0	....	50.00
T 6	60	....	18.5	....	18.7	28.1	72	....	95.3	....	53.75	....
56	......	145	......	19.8	......	38.6	......	0	......	0	....	48.50
57	......	117	......	19.0	......	33.2	......	0	......	0	....	51.25
T 7	57	117	18.6	18.8	19.6	34.3	68	0	95.6	0	53.50	50.00
58	......	131	......	18.5	......	30.4	......	0	......	0	....	49.25
59	......	69	......	18.6	......	22.0	......	65	......	94.5	....	51.75
60	......	58	......	18.5	......	20.8	......	78	......	90.2	....	52.75
T 8	53	63	18.7	18.9	19.5	22.6	45	75	94.8	96.6	53.50	52.25

CHANGE IN TEMPERATURE AND CONDITION OF THE DRIED CORN IN HOLD NO. 3.

Hold 3 contained artificially dried corn, all of which, excepting a small amount along the bottom, became hot and badly damaged during the voyage. Even the corn along the bottom, although it did not get hot, was sour, moldy, and badly packed when discharged. The average temperature of this dried corn when it was loaded was about 15° F. higher than the average for the natural corn in the other four holds of the ship. In that part of the corn that was located away from the boiler-room bulkhead, the greatest change in temperature took place in the upper portion. The temperature of the corn near the surface increased 13° F. the first 17 days after it was loaded, after which the increase was more rapid, reaching 137° F. when the ship reached port, as is shown by the temperature record of thermometer 9 in figure 20. The temperature of the corn in the central part of the hold, about 4 feet under the surface, increased in about the same manner as the corn at the surface, but the temperature was generally somewhat lower, having a temperature record of 135° F. on April 7, as is shown by the readings for thermometer 11. The temperature of the corn stowed a little over half way down in the center of the hold increased but little during the first nine days, but from then on steadily increased until 107° F. was reached on April 8, as shown by the temperature record for thermometer 14.

The temperature of the corn near the center of the bottom of the hold increased 19 degrees during the first two weeks, reaching its maximum of 89° F. April 14, after which it gradually became cooler, being affected by the water temperature, and dropped to 79° on April 8.

TABLE 13.—*Condition of the dried corn in hold 3 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the hold, from top to bottom.*

[T 9, etc., represents samples in crossed-wire containers, fastened to resistance thermometers of the same numbers; * indicates not included in the averages.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	°F.	*°F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Pounds.*	*Pounds.*
T 9	70	137	15.6	18.3	24.1	41.4	44	0	85.0	0	54.75	45.25
*61	......	*155	......	*54.6	......	*110.8	......	*0	......	*0	....	....
T 10	74	91	15.5	16.2	21.6	42.0	38	5	90.5	38.0	54.00	50.50
T 11	71	135	15.4	14.8	21.3	35.7	38	0	94.4	0	54.25	53.00
T 12	68	134	15.3	14.6	23.2	36.8	48	0	92.8	0	54.00	52.50
62	......	115	......	15.4	......	32.0	......	0	......	23.2	....	50.50
T 19	68	106	15.8	13.6	22.1	36.7	61	2	92.8	34.4	54.25	50.50
T 20	68	74	15.6	13.0	21.7	23.5	42	43	96.5	85.8	54.25	54.00
63	......	108	......	15.5	......	29.8	......	0	......	33.6	....	52.00
T 14	68	107	15.5	15.2	21.5	29.5	44	15	95.7	76.9	54.25	53.25
T 13	67	109	15.2	14.2	21.5	24.6	34	21	94.0	85.3	55.00	53.50
T 15	65	105	15.3	15.0	20.4	26.5	38	18	95.0	83.5	54.75	52.00
18	71	....	15.8	....	21.6	....	50	....	95.5	....	54.50	....
T 17	70	89	15.8	15.6	22.1	28.0	47	31	94.8	90.0	54.75	53.50
16	70	78	15.2	15.3	21.8	25.2	35	36	94.9	93.7	54.25	53.75

As is shown in Table 13, the corn became badly damaged in the upper part of the hold, the degree of damage gradually decreasing toward the bottom. It will be seen in Table 10 that the averages for various factors in the analyses of the corn as discharged were as follows: Acidity 31.6 c. c., germination 13.2 per cent, sound kernels 49.6 per cent, and 51.86 pounds test weight per bushel, which, compared with the average condition of the corn as loaded, was an increase of 9.9 c. c. in acidity and a decrease of 30 per cent in germination; 43.9 per cent in sound kernels; and a little over 2.5 pounds in test weight per bushel.

INFLUENCE OF BOILER HEAT ON THE CORN.

There were three main boilers and two donkey boilers in the stokehold. The donkey boilers were located near the middle of the bulkhead which separated the stokehold from hold 3. This bulkhead was lined with a plank sheeting on the cargo side, but there was no second bulkhead to form an air space. There were coal bunkers over and on both sides of the stokehold, as is shown in figures 20 and 22. Steam was kept up in the donkey boilers during the loading period, and the effect of the heat generated was plainly noticeable on the corn stowed contiguous to this bulkhead opposite the boilers, as is shown by the temperature records for thermometers 13, 14, and 15 in figure 21. The corn located next to the bulkhead opposite the donkey boilers showed a rapid increase in temperature at the time of loading, while steam was kept up in the boilers, and showed a higher temperature than the corn located the same height but some distance back from the bulkhead until March 27, when it was lower. When steam was again generated in the donkey boilers at the end of the voyage, the effect of the heat on the corn stowed next to the bulkhead opposite the boilers became apparent, the temperature increasing 20 degrees in two days. The corn near the surface which was stowed along the bulkhead that separated hold 3 from the coal bunker did not get as hot as the corn that was stowed the same height back from the bulkhead, as is shown by the temperature records for thermometers 10, 11, and 12. The hatch over the coal bunker was kept open and afforded ventilation in the bunker until March 18, but during the next week, when rough weather was encountered and the hatch was kept closed, the temperature of the corn contiguous to the bulkhead increased 23 degrees, as is shown by the temperature record for thermometer 10. The corn stowed along the bottom of hold 3 near the boiler-room bulkhead had a lower temperature during the greater part of the voyage than the corn some distance away, and this can be accounted for in that the temperature at the bottom of the boiler room was kept cool by the fresh air that rushed from the ventilators and took the place of the heated air that was forced out at the top.

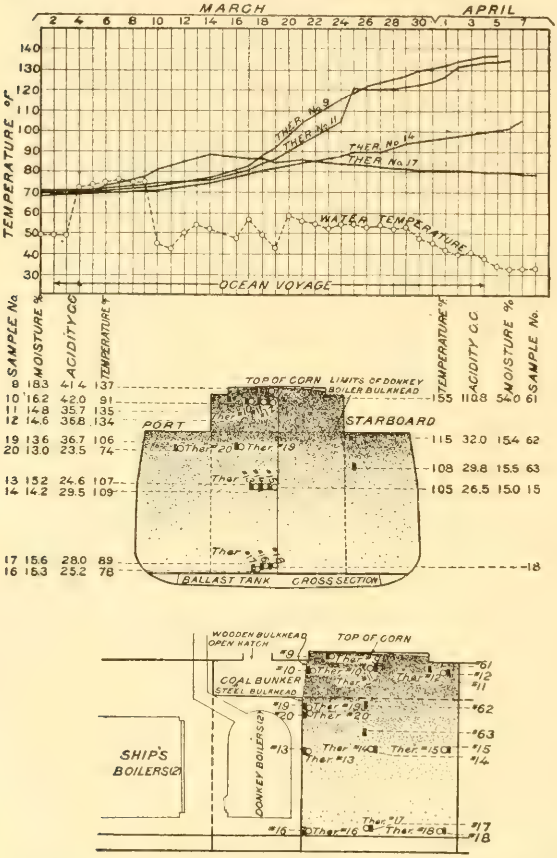


FIG. 20.—Hold 3: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

The effect on the corn of the heat generated in the boilers is shown further by the temperature records of thermometers 19 and 20, which were located against the upper part of the bulkhead, 19 opposite the boilers and 20 ten feet away opposite a ventilated coal bunker, as shown in figure 22. Thermometer 19 registered an increase of 17° F. the first two days after the corn was loaded, while thermometer 20 registered an increase of only 1° F. during this time. Thermometer 19 registered a higher temperature than thermometer 20 during the whole voyage. Thermometer 19 registered over 100° F. from March 16 to March 26, after which the temperature steadily dropped until April 2, when steam was again generated in the donkey boilers, the heat immediately affecting the temperature of the corn, which increased 22 degrees in four days. On April 6 the corn surrounding thermometer 19 had a temperature of 106° F. as compared with a temperature of but 59° F. for the corn surrounding thermometer 20.

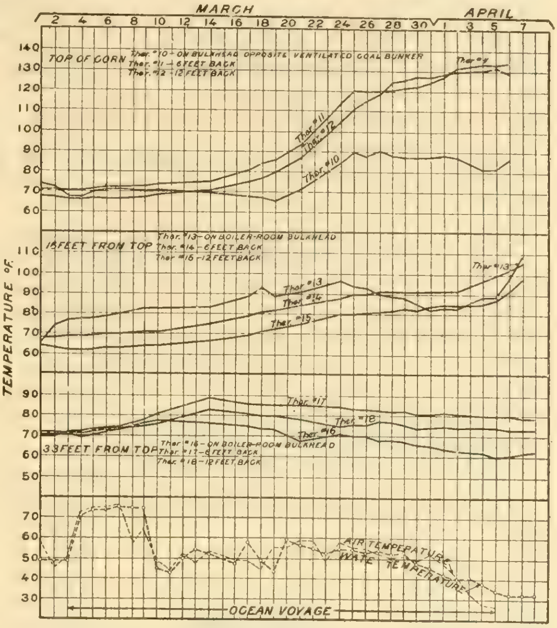


FIG. 21.—Hold 3: Temperature records showing the effect of boiler heat on the temperature of corn. (Cargo No. 2.)

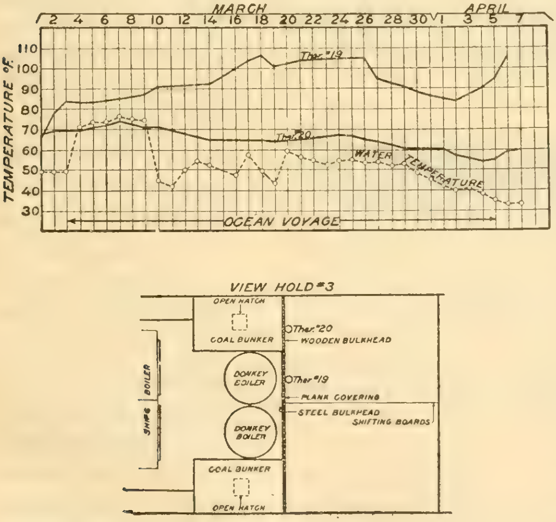


FIG. 22.—Hold 3: Temperature records showing the effect of boiler heat on the temperature of corn. (Cargo No. 2.)

It will be seen in Table 14 that the corn surrounding thermometer 19, opposite the donkey boilers, underwent by far the most deterioration. Sample

No. 19, which was fastened to thermometer 19, as compared with sample No. 20, which was fastened to thermometer 20, showed a greater increase in acidity during the voyage by 10.8 c. c., and a greater decrease in germination by 59 per cent, sound kernels by 47 per cent, and weight per bushel by 3.5 pounds.

CHANGE IN TEMPERATURE AND CONDITION OF THE NATURAL CORN IN HOLD NO. 4.

During the voyage the natural corn in hold 4 became hot and badly damaged in the upper part of the hold and along the shaft tunnel in the bottom, as is shown in figure 23. The greatest damage in the corn occurred near the surface and decreased with the distance downward.

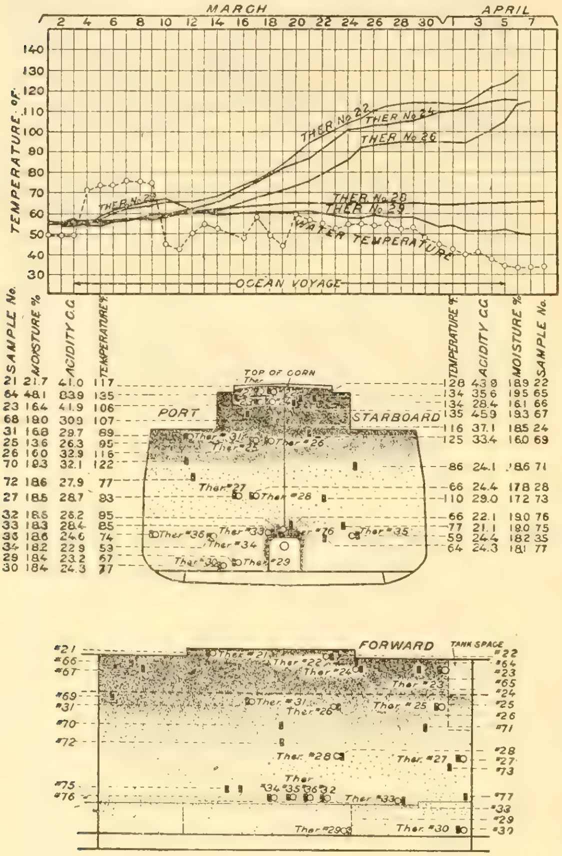


FIG. 23.—Hold 4: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

The temperature of the corn in this hold as loaded varied from 50° to 62° F. In the first 11 days of the ocean voyage ending March 12, the temperature near the surface about 20 feet back from the engine-room bulkhead increased from 55° to 68° F.; by March 29 the temperature had reached 114° F. and by April 6, it was 128° F. as shown by the temperature record for thermometer 22 in figure 23. The temperature of the corn located about 4 feet down increased at about the same rate as at the surface, but did not start to increase so soon; the temperature at this point was 115° F. on April 6, as compared with 128° F. for the surface corn. (See temperature record for thermometer 24.)

It was still longer before the increase in temperature of the corn located about 12 feet below the surface began to be pronounced.

By March 26, the temperature had increased to 93° F., after which it remained practically stationary until April 2, but during the next five days it showed a rapid increase and was 116° F. on April 7, as is shown by the temperature record for thermometer 26. It should be noted that the temperature increased rapidly in the three positions mentioned from the 12th to the 24th of March, a period of the voyage during which the weather was rough. Thermometer 28, located about two-thirds of the distance down in the hold, indicated a temperature of 66° F. on April 8, which was an increase of but 9 degrees during the voyage. The temperature of the corn near the bottom of the hold varied somewhat with the water temperature, reaching its maximum of 67° F. on March 10, after which it gradually decreased to 49° F. on April 7, at which time the water temperature was 33° F.

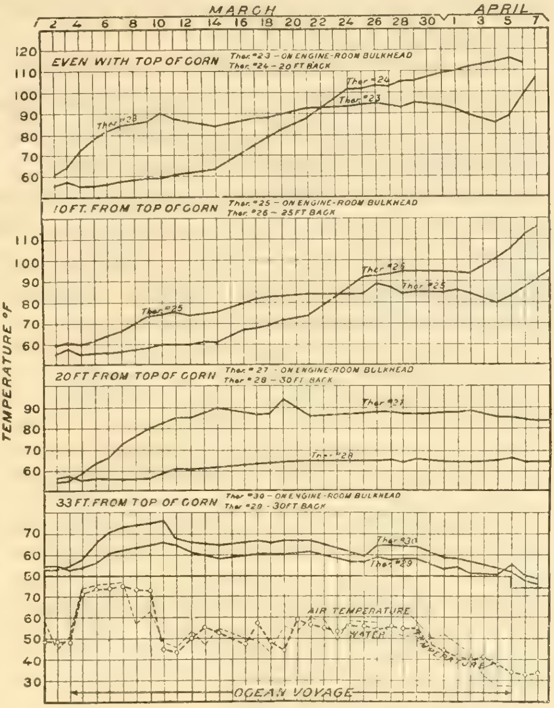


FIG. 24.—Hold 4: Temperature records showing the effect of heat from the engines on the temperature of corn. (Cargo No. 2.)

TABLE 14.—*Effect of boiler heat on the corn.*

Sample No.	Location along the bulkhead.	Increase.		Decrease.			
		Temperature.	Acidity.	Moisture.	Germination.	Sound kernels.	Weight per bushel.
		° *F.*	*c. c.*	*Per cent.*	*Per cent.*	*Per cent.*	*Pounds.*
19	Opposite donkey boiler	38	12.6	2.2	59	58.4	3.75
20	Opposite coal bunker	6	1.8	2.6	(1)	10.7	.25

[1] No change.

Note that the temperature of the corn was over 100° F. near the surface for 14 days before it was discharged, 4 feet under the surface for 13 days, and 12 feet under the surface for 3 days.

INFLUENCE OF ENGINE HEAT ON THE CORN.

It will be seen by the temperature records in figure 24 that the temperature of the corn located next to the bulkhead separating hold 4 from the engine room was influenced to a considerable extent by the temperature in the engine room, expecially during the early part of the voyage.

There was an unventilated water-tank space next to the engine room bulkhead in the upper part of the hold, which was separated from the cargo space by a board bulkhead that was not air-tight. Thermometer 23, which was located next to the tank-space bulkhead in the upper part of the corn, indicated an increase from 60° to 90° F., or an increase of 30 degrees the first 8 days ending March 10, during which time the corn stowed the same height but about 20 feet back from the bulkhead increased only 3 degrees and did not reach 90° F. until about March 21, 11 days later.

TABLE 15.—*Condition of the natural corn in hold 4 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the hold, from top to bottom.*

[T 21, etc., represents samples in crossed-wire containers, fastened to resistance thermometers of the same numbers; * indicates not included in the average.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	°F.	*°F.*	*P. ct.*	*P. ct.*	*c.c.*	*c.c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Pounds.*	*Pounds.*
T 21	52	117	19.5	21.7	20.1	41.0	60	0	95.5	0	53.25	45.50
T 22	54	128	19.1	18.9	20.2	43.9	73	0	91.1	0	53.50	43.25
*64	......	*135	......	*41.1	......	*83.9	......	*0	......	*0	....	....
65	......	134	......	19.5	......	35.6	......	0	......	13.7	....	48.00
66	......	134	......	16.1	......	28.4	......	0	......	0	....	48.25
67	......	135	......	19.3	......	45.9	......	0	......	0	....	45.50
T 23	56	106	19.3	16.4	20.0	41.9	73	6	94.0	29.6	52.50	49.50
T 24	56	116	19.0	18.5	24.6	37.1	58	0	93.0	0	54.50	51.00
68	......	107	......	19.0	......	30.9	......	0	......	15.9	....	49.00
69	......	125	......	16.0	......	33.4	......	0	......	0	....	49.50
T 31	56	89	18.6	16.8	19.5	29.7	63	22	94.4	55.8	54.25	50.75
T 25	60	95	18.6	13.6	20.1	26.3	73	52	97.5	86.4	53.50	....
T 26	56	116	18.5	16.0	18.6	32.9	62	16	92.8	42.7	53.75	49.75
70	......	122	......	19.3	......	32.1	......	0	......	34.5	....	49.25
71	......	86	......	18.6	......	24.1	......	38	......	84.7	....	50.50
72	......	77	......	18.6	......	27.9	......	29	......	83.0	....	51.00
T 27	57	93	18.6	18.5	19.2	28.7	70	0	96.3	57.2	53.00	48.00
T 28	56	66	18.8	17.8	18.7	24.4	66	68	95.9	95.8	54.00	53.00
73	......	110	......	17.2	......	29.0	......	6	......	49.5	....	51.00
75	......	77	......	19.0	......	21.1	......	54	......	85.8	....	51.75
76	......	66	......	19.0	......	22.1	......	42	......	91.9	....	52.00
T 32	57	85	19.1	18.6	21.1	26.2	58	27	94.1	89.7	52.00	50.00
T 33	57	95	19.0	18.3	20.7	28.4	70	9	92.7	55.5	53.75	50.00
T 36	53	74	19.2	18.6	18.5	24.6	68	65	95.5	96.0	53.25	51.50
T 34	55	59	18.8	18.2	18.7	22.9	71	69	95.1	86.5	54.00	53.50
77	......	64	......	18.1	......	24.3	......	22	......	84.6	....	48.75
T 35	55	59	18.7	18.2	20.3	24.4	61	69	97.0	95.4	54.00	53.25
T 30	54	77	19.7	18.4	20.4	24.3	67	59	94.2	86.0	53.50	52.50
T 29	55	67	18.9	18.4	19.8	23.2	77	68	95.4	94.5	53.25	52.25

During the first part of the voyage, to March 23, thermometer 25, located against the lower part of the tank-space bulkhead about 10 feet from the surface, also indicated a higher temperature than thermometer 26, located the same height but some distance back in the hold. During the remainder of the voyage the temperature of the corn stowed next to the tank-space bulkhead did not vary a great deal until the last few days when it increased 21 degrees in 3 days near the surface of the corn and 15 degrees in 4 days 10 feet below the surface. The temperature of the corn stowed back from the tank space continued to increase irregularly during the whole of the voyage and reached 115° F. near the surface and 116° F. 10 feet below the surface before it was discharged. Thermometer 27, located next to the engine room bulkhead about 20 feet from the surface of the corn indicated an increase from 56° to 90° F., or an increase of 34 degrees during the first 12 days ending March 14, as compared with an increase from 56° to 62° F., or 6 degrees, in the corn stowed the same height but some distance back from the bulkhead, as was indicated by thermometer 28. From March 14 on there was but little change in either position. The temperature of the corn near the bottom varied somewhat with the water temperature, as is shown by the temperature records for thermometers 29 and 30, that near the bulkhead being generally somewhat higher than the corn some distance back.

The corn stowed next to the tunnel was affected by the heat which penetrated the tunnel from the engine room, the details of which are explained under the discussion of the changes that took place in the corn in hold 5.

The changes in the condition of the corn during the voyage in various positions of stowage in the hold are shown in Table 15. The averages of the corn as discharged were: Acidity 29.8 c. c., germination 25.8 per cent, sound kernels 54.1 per cent, and 49.93 pounds test weight per bushel, which was an average increase during the voyage of 9.8 c. c. in acidity, and an average decrease of 41.1 per cent in germination, 40.5 per cent in sound kernels, and a little over 3.5 pounds in test weight per bushel.

CHANGE IN TEMPERATURE AND CONDITION OF THE NATURAL CORN IN HOLD NO. 5.

About one-fifth of the natural corn in hold 5 became heat damaged while it was in the vessel. The heating corn was found at the top to about one-fourth the distance down and also along the shaft tunnel. In the heating corn on top the highest temperature and the greatest damage were found at the surface, while in the heating corn along the shaft tunnel, the highest temperature and the greatest damage were found in the corn located against the tunnel.

The temperature of the corn in this hold at time of loading varied from 53° to 55° F. During the voyage the corn near the surface on a level with the main deck gradually increased in temperature until it reached a maximum of 122° F. on April 2, 3 days before the ship was docked, as is shown by the temperature records for thermometer 38 in figure 25. The temperature of the corn about

5 feet below the surface and the remainder of the corn in the hold, excepting that which was located on and near the shaft tunnel, changed but little before the cargo arrived in Denmark, as is shown by the temperature records for thermometers 38 and 41. But, during the discharge of the cargo, which took 15 days, the corn at the new surfaces formed from day to day would frequently get hot from one day to another. Thus the corn nearly halfway down in the hold was cool and sound when it was first exposed but got hot before it was discharged, as is shown by sample No. 82 in figure 25, which had a temperature of 112° F. This same condition also occurred in the corn in hold 4.

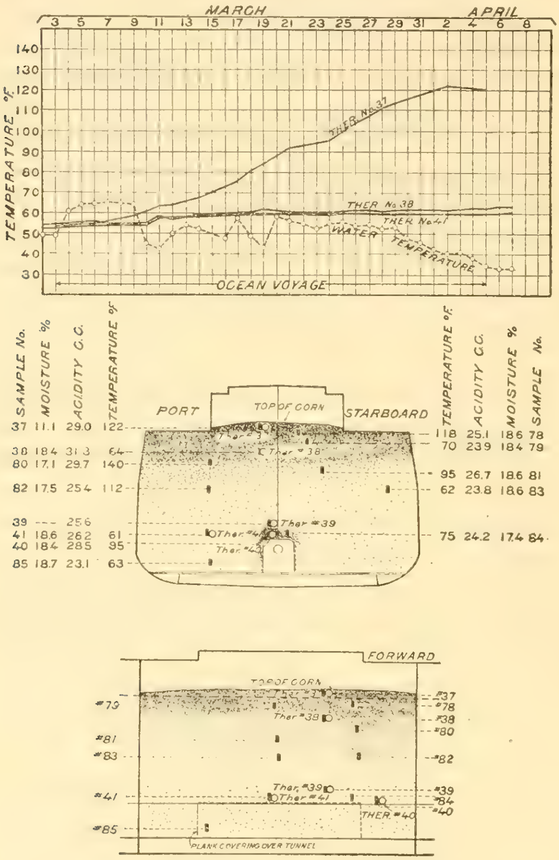


FIG. 25.—Hold 5: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

Table 16 shows the condition of the individual samples as discharged as compared to the condition as loaded. It will be seen in Table 10 that the averages for the corn as discharged were: Acidity, 26.3 c. c., germination 29.9 per cent, sound kernels 72.9 per cent, and weight per bushel 50.6 pounds, which was an average increase from the condition as loaded of 5.9 c. c. in acidity, and an average decrease of 36.9 per cent in germination, 21.1 per cent in sound kernels, and 2.75 pounds in test weight per bushel.

INFLUENCE OF TUNNEL HEAT.

The temperature of the corn located next to the shaft tunnel in holds 4 and 5 was noticeably affected by the tunnel temperature, as is shown in figures 26 and 27. The tunnel was constructed from steel and was unprotected, excepting that part of it which was directly under the hatches, where it had a plank covering. In hold 4, five thermometers were placed in the corn the same height as the top of the tunnel, as is illustrated in figure 26. Thermometer 36 was located on the steel side of the ship, where the temperature varied with and was always about the same as that of the sea water. Two thermometers were placed halfway between the tunnel and the outside, thermometer 34 on the port side and 35 on the starboard side, and the temperature of the corn in both of these positions remained practically the same throughout the whole of the voyage. The two remaining thermometers were placed on the tunnel, thermometer 32 on the unprotected steel part and 33 on the plank protected part. The temperature records for thermometers 32 and 33 show that the temperature next to the tunnel remained unchanged until the ship began to sail at the beginning of the voyage, after which there was an immediate and rapid increase during the next seven days, reaching a maximum of 95° F. on March 10. During this period the corn that was located against the steel part of the tunnel was the first to show a rapid increase, and also the greatest daily increase, in temperatures. After March 10 there was a decided drop in both the air and water temperatures, and also a corresponding drop in the temperature of the corn next to the tunnel. The corn, however, remained above 80° F. until April 1, after which there was again a decided drop in temperature corresponding to the drop in the air and water temperatures at this time. The corn located against the steel part of the tunnel was, however, in this case the first to show the decrease, and also showed the greatest daily decrease, a condition which was just the reverse of that at the beginning of the voyage. This illustrates the fact that the unprotected steel tunnel is a better conductor of heat than when it is protected by a plank sheeting. During practically the whole of the voyage, the temperature of the corn stowed next to the tunnel was over 20 degrees higher than the temperature of the corn stowed halfway out from the tunnel.

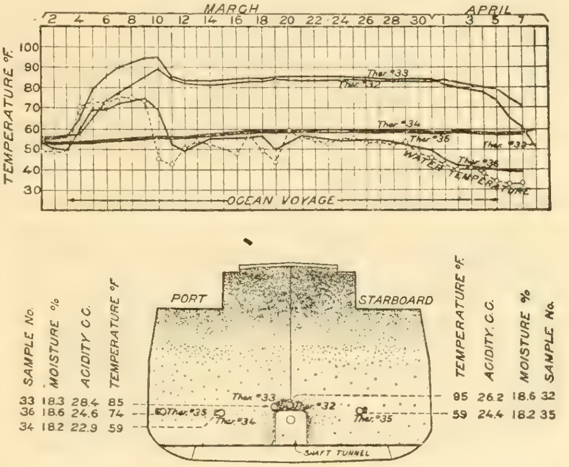


FIG. 26.—Hold 4: Temperature records of the electrical resistance thermometers and "trap" samples located at the height of the top of the shaft tunnel. Samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

TABLE 16.—*Condition of the natural corn in hold 5 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the hold, from top to bottom.*

[T 37, etc., represents samples in crossed-wire containers fastened to resistance thermometers of the same numbers; * indicates not included in the average.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	°*F.*	°*F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Pounds.*	*Pounds.*
T 37	53	122	19.1	11.1	19.9	29.0	75	20	93.2	47.7	53.75	51.00
78	......	118	......	18.6	......	25.1	......	0	......	61.0	....	49.50
79	......	70	......	18.4	......	23.9	......	55	......	93.7	....	52.00
T 38	53	64	19.2	18.4	22.4	31.3	66	55	90.3	89.0	52.50	52.00
80	......	140	......	17.1	......	29.7	......	0	......	0	....	47.75
81	......	95	......	18.6	......	26.7	......	30	......	80.0	....	49.25
82	......	112	......	17.5	......	25.4	......	44	......	88.6	....	49.25
83	......	62	......	18.6	......	23.8	......	49	......	95.7	....	50.25
T 39	54	71	18.7	....	19.5	29.6	62	4	95.9	89.8	53.25	....
T 40	55	95	18.4	18.4	19.9	28.5	63	0	95.1	35.2	53.50	51.00
84	......	75	......	17.4	......	24.2	......	13	......	87.2	....	51.00
T 41	54	61	18.3	18.6	20.6	26.2	68	58	95.5	84.8	53.75	52.00
85	......	63	......	18.7	......	23.1	......	61	......	92.4	....	51.75

The influence of the tunnel heat on the corn in hold 5, is illustrated by the temperature records for thermometers 39, 40, and 41 in figure 27. Thermometer 40 was located on the steel part of the tunnel, thermometer 39 about 3 feet above the plank covered part of the tunnel, and thermometer 41 the same height as the top of the tunnel but halfway out toward the side of the ship. Thermometer 40 indicated a rapid increase in temperature during the first week after the vessel sailed, and registered 95° F. on March 10. The temperature decreased to 86° F. on March 11, after which it did not vary much until the steamship arrived at Denmark, when the temperature dropped 16 degrees in four days. The temperature of the corn along the tunnel varied with the water and air temperature, but was considerably higher after the first few days. Thermometer 39 located 3 feet above the plank covered part of the tunnel registered

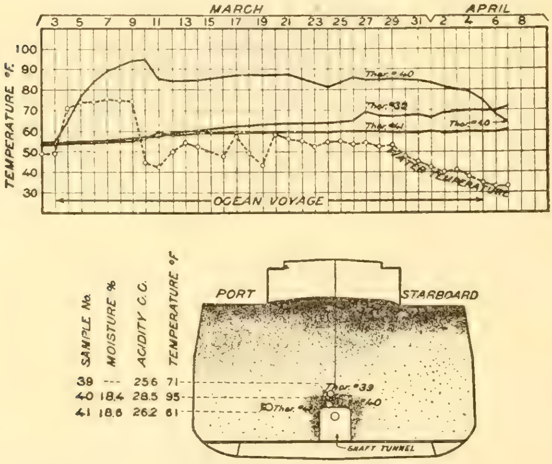


FIG. 27.—Hold 5: Temperature records of the electrical resistance thermometers, location of the thermometers, and "trap" samples located at the height of the top of the shaft tunnel. Samples secured in Denmark. Heavy shading represents heat-damaged corn. (Cargo No. 2.)

an increase of but 17 degrees during the voyage, and thermometer 41 located halfway out registered an increase of only 7 degrees. The temperature of the corn stowed against the tunnel did not go above 95° F. in either hold, but the corn became sour and moldy and was in a dangerous condition for storage after it was discharged.

TABLE 17.—*Changes that took place in the condition of the corn located on the shaft tunnel compared with the changes in the corn stowed the same height in the holds but located halfway between the tunnel and the side of the vessel.*

Sample No.	Location.	Increase in temperature.	Decrease in moisture content.	Increase in acidity.	Decrease in germination.	Decrease in sound kernels.	Decrease in weight per bushel.
		° *F.*	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 4:							
32	On tunnel, wooden part	28	0.5	25.5	31	4.4	2.00
33	On tunnel, steel part	38	.7	38.5	61	37.2	3.75
32 and 33[1]	On tunnel	33	.6	32.0	46	20.8	2.87
34 and 36[2]	Tunnel height, halfway out	12	.6	25.7	2	4.0	1.12
Hold 5:							
40	On tunnel	40	.0	42.5	63	59.9	2.50
41	Tunnel height, halfway out	7	[3].3	28.0	10	10.7	1.75

[1] Data represent averages for samples Nos. 32 and 33.
[2] Data represent averages for samples Nos. 34 and 36.
[3] Increase.

It will be seen in Table 17 that the corn stowed against the tunnel underwent a more severe deterioration than the corn stowed the same height but halfway out toward the side of the hold; and also, that the corn stowed along the steel side of the tunnel became more damaged than the corn stowed against the plank covered part of the tunnel.

"SWEAT" AND FERMENTATION IN THE HOLDS.

The effects of "sweat" were shown very distinctly immediately under the hatch combings and deck beams in each hold. The "sweat" which condensed on the under side of the deck fell on the surface of the corn where it supplied the necessary moisture for fermentation. While the amount of corn that was damaged by "sweat" alone was not very large, the fermentation which it started and the heat which was generated, spread to the unaffected parts and in that way caused much damage as a result of the long voyage. This condition usually happens early in the voyage. Table 18 shows the result of "sweat" on the corn located immediately under the hatch beams.

TABLE 18.—*Effect of "sweat" on the corn which was located immediately under the hatch beams.*

Sample No.	Hold No.	Temperature.	Moisture content.	Weight per bushel.	Germination.	Acidity.	Sound kernels.
		° *F.*	*Per cent.*	*Pounds.*	*Per cent.*	*c. c.*	*Per cent.*
43	1	110	43.6	(1)	0	65.7	0
52	2	138	34.6	48.00	0	75.5	0
61	3	155	54.6	(1)	0	110.8	0
64	4	135	48.1	(1)	0	83.9	0

[1] Too wet.

In fermenting corn, the moisture contained within the kernels is liberated quite rapidly, and escapes in the form of vapor. After the cargo arrived in Aalborg, the hot corn under the hatch in hold 2 was discharged to a depth of about 8 feet, and then the hatch closed again. While the hatch was open, there was no "sweat" dropping from the hatch beams because the heated moisture-laden air escaped through ventilation, but, a short time after the hatch had been closed the water was found to be dripping from the deck and hatch beams quite rapidly, which stopped again after the hatch had been opened a few minutes. During the voyage all of the ventilators leading to the corn were kept closed.

CORRELATION OF THE CHANGES IN THE TEMPERATURE OF THE CORN AND THE CHANGES IN SOUND KERNELS, ACIDITY, GERMINATION, AND TEST WEIGHT PER BUSHEL.

It was seen in the tables giving the detailed analyses of the samples that considerable change took place in the temperature and condition of the corn in the various positions of stowage while the corn was in the vessel. The increase in the temperature of the corn in the holds of a vessel is brought about principally through (1) inherent causes, usually fermentation, which produces heat, and (2) external influences, such as higher air and sea-water temperatures and the heat from the ship's machinery, which penetrates the cargo holds and frequently induces fermentation. As the corn in bulk does not afford sufficient ventilation for the heat to escape, the temperature continues to increase until the corn gets hot. The maximum temperature recorded in this cargo as discharged was 155° F.

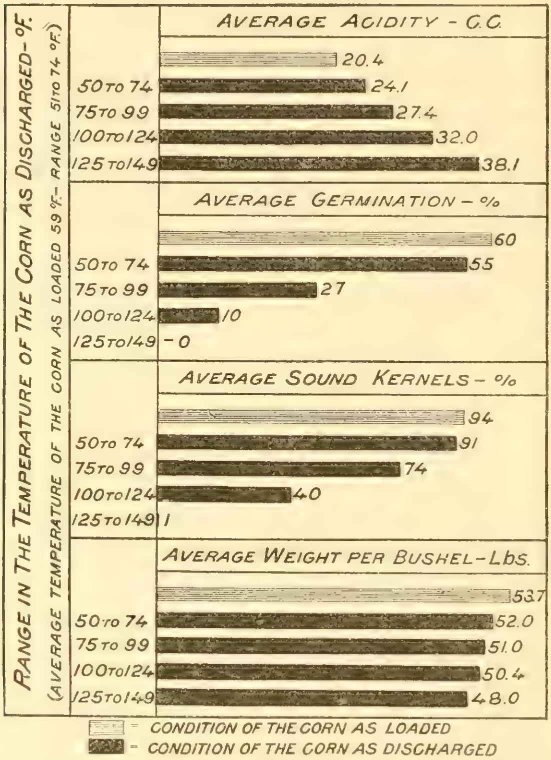


FIG. 28.—Diagram showing the correlation of the temperature and condition of the corn samples in crossed-wire containers as loaded and as discharged. (Cargo No. 2.)

The temperature of hot corn often decreases after the corn has been fermenting for some time, due no doubt to the more or less complete destruction of the compounds and tissues upon which the biochemical processes act.

By examining figure 28, it will be seen that there is a close relation between the deterioration of the corn and the increase in temperature.

CARGO No. 3.

Cargo No. 3 consisted of 145,714 bushels of natural corn. The corn was loaded December 22 and 23, 1911. The vessel sailed December 24 and arrived in Bremerhaven January 7, where the corn was discharged from January 10 to 14. The length of the ocean voyage was 14 days. The maximum time that any of the corn was in the vessel was 23 days and the average time 21 days.

STOWAGE OF THE CORN.

The steamship had six cargo holds, as is shown in figure 29, and each of the holds was only partly filled with corn. The vessel had two shaft tunnels running through the bottom of holds 3, 4, 5, and 6, one of which carried steam pipes that supplied the steam for the rudder machinery. Both tunnels were ventilated.

CONDITION OF THE CORN AS LOADED.

The condition of the corn as loaded is shown in Tables 19 and 20. The averages for the various factors in the corn as loaded were as follows: Moisture content 19.3 per cent, acidity 16.8 c. c., germination 73.4 per cent, sound kernels 93.4 per cent, weight per bushel 54.5 pounds. The corn at this time had an average temperature of 32° F. It will be noted that the corn was in very sound condition as indicated by the extremely low acidity test of 16.8 c. c.

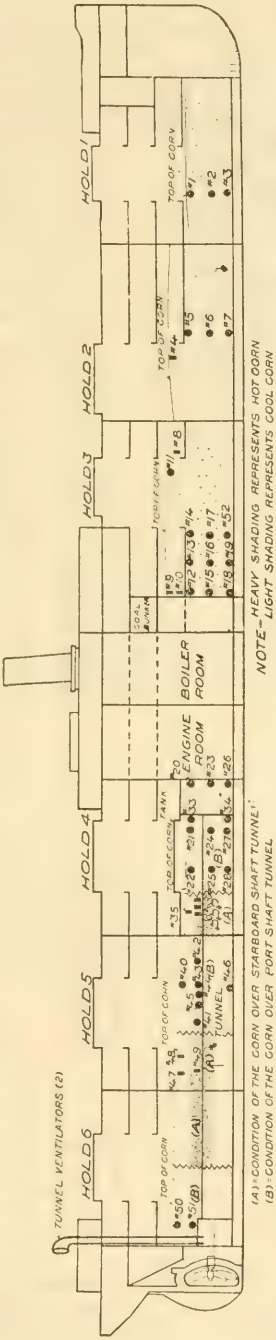

HOLD 1
HOLD 2
HOLD 3
HOLD 4
HOLD 5
HOLD 6
TOP OF CORN
COAL BUNKER
BOILER ROOM
ENGINE ROOM
TANK
TUNNEL
TUNNEL VENTILATORS (2)
NOTE—HEAVY SHADING REPRESENTS HOT CORN
LIGHT SHADING REPRESENTS COOL CORN
(A)=CONDITION OF THE CORN OVER STARBOARD SHAFT TUNNEL
(B)=CONDITION OF THE CORN OVER PORT SHAFT TUNNEL

FIG. 29.—Diagram showing arrangement of the steamship and stowage of the corn in holds. The heavy shading represents heat-damaged corn discharged. (Cargo No. 3.)

TABLE 19.—*Range in the principal factors showing quality and condition of the corn in cargo No. 3, as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° F.	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 1:						
As loaded	32.0- 32.0	18.7-19.0	14.0-15.0	74.0-80.0	90.8-94.5	54.0-55.5
As discharged	36.0- 37.0	18.1-18.6	18.5-20.5	79.0-82.0	89.8-95.8	53.7-54.2
Hold 2:						
As loaded	30.0- 31.0	18.3-18.8	15.5-16.5	71.0-81.0	93.1-95.3	53.5-55.5
As discharged	34.0- 41.0	17.4-18.8	17.5-20.5	66.0-78.0	92.0-94.3	53.5-56.0
Hold 3:						
As loaded	31.0- 32.0	18.1-19.7	14.0-18.0	71.0-80.0	90.8-96.2	54.0-55.5
As discharged	33.0- 48.0	17.6-19.4	16.0-19.0	60.0-87.0	82.8-97.0	52.3-55.0
Hold 4:						
As loaded	31.0- 46.0	19.1-20.6	16.0-20.5	61.0-78.0	91.2-94.7	53.0-56.0
As discharged	42.0-132.0	17.9-26.8	18.0-46.0	0-82.0	0-96.3	41.5-56.0
Hold 5:						
As loaded	27.0- 32.0	19.1-20.8	16.5-19.0	55.0-85.0	90.6-95.7	52.0-55.0
As discharged	32.0-119.0	18.6-22.9	17.5-37.0	0-84.0	0-95.8	46.0-54.5
Hold 6:						
As loaded	28.0- 32.0	18.4-19.3	15.5-17.0	82.0-91.0	95.7-98.7	55.0-56.0
As discharged	37.0- 52.0	18.3-18.9	18.0-18.0	80.0-91.0	92.1-97.1	54.5-55.0

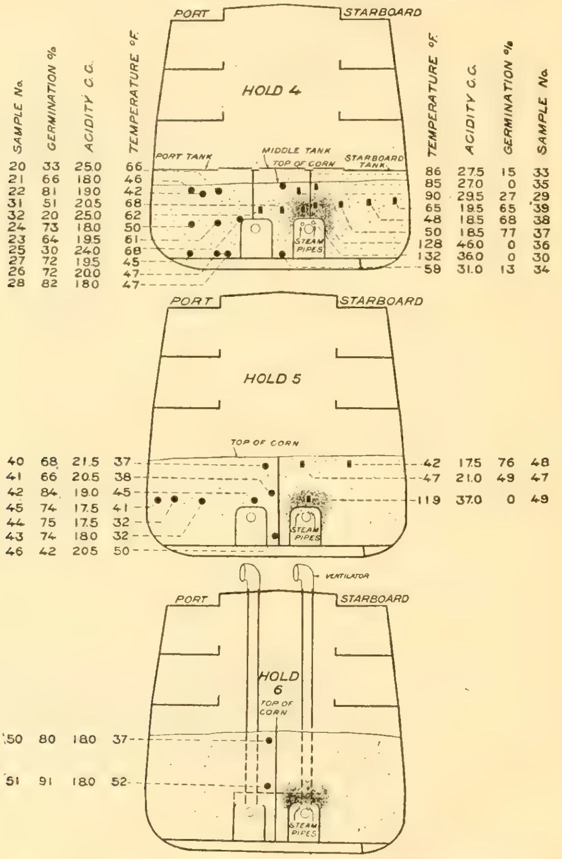


FIG. 30.—Illustrating the position of stowage of the corn in holds 4, 5, and 6, cargo No. 3, and the effect of the heat from the shaft tunnel on the corn surrounding the starboard tunnel. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 3.)

TABLE 20.—*Condition of the corn in cargo No. 3 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

Hold and sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1:	*° F.*	*° F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
1	32	36	18.9	18.5	15.0	20.0	79	82	90.8	90.9	55.50	54.00
2	32	37	18.7	18.6	14.0	20.5	73	80	91.5	89.8	54.50	54.50
3	......	......	19.0	18.1	15.0	18.5	79	79	94.5	95.8	54.00	53.75
Hold 2:												
4	......	41	......	17.9	......	18.0	......	78	......	92.7	......	56.00
5	31	35	18.3	18.2	15.5	17.5	70	75	93.1	92.0	53.50	54.00
6	30	39	18.7	17.4	16.5	20.5	73	66	95.3	93.1	54.50	54.50
7	31	33	18.8	18.8	16.0	19.0	80	75	95.0	94.3	55.50	53.50
Hold 3:												
8	......	42	......	19.2	......	19.0	......	75	......	89.1	......	55.00
9	......	45	......	19.0	......	17.5	......	75	......	94.6	......	54.00
10	......	48	......	19.4	......	19.0	......	60	......	88.3	......	53.00
11	32	37	18.2	17.5	17.5	17.0	75	71	92.1	93.6	55.00	54.00
12	30	43	19.7	18.1	15.5	18.0	73	76	93.5	94.0	54.00	52.50
13	31	33	19.0	18.4	16.5	17.0	74	69	95.2	97.0	54.00	52.25
14	31	36	18.5	18.7	14.0	18.5	78	77	96.2	82.8	55.00	53.50
15	31	43	18.7	18.0	16.0	16.0	73	77	94.2	97.0	55.00	54.50
16	31	34	18.1	17.9	17.0	16.0	79	85	90.8	95.1	55.50	54.25
17	32	33	19.1	18.8	17.5	18.0	70	76	91.5	93.9	54.50	53.75
18	32	38	19.2	19.0	18.0	17.5	73	83	92.9	91.0	54.00	54.50
19	32	41	18.7	17.6	14.5	19.0	77	74	93.6	92.6	55.00	54.00
Hold 4:												
Port side—												
20	46	66	19.6	18.6	17.0	25.0	67	33	93.0	59.0	55.00	50.75
21	33	46	19.1	18.9	17.5	18.0	67	66	93.2	90.4	56.00	55.00
22	32	42	19.3	18.7	18.0	19.0	61	81	91.2	87.7	53.50	54.00
23	36	61	19.5	19.0	17.0	19.5	78	64	92.9	92.2	55.00	52.75
24	31	50	19.4	19.0	17.0	18.0	70	73	94.7	87.3	55.00	53.00
25	34	68	19.3	18.5	16.5	24.0	69	30	93.0	75.2	54.50	50.75
26	37	47	19.8	18.6	19.0	20.0	69	72	92.2	89.4	53.00	53.25
27	32	45	19.6	19.3	17.0	19.5	67	72	92.0	90.2	54.00	52.75
28	34	47	19.7	18.7	17.0	18.0	70	82	93.9	88.7	54.50	53.00
Middle—												
33	33	86	19 3	18.4	16.0	27.5	76	15	93.8	55.6	55.00	50.50
29	......	90	......	18.6	......	29.5	......	27	......	51.2	......	45.25
30	......	132	......	18.6	......	36.0	......	0	......	......	......	43.50
31	......	68	......	19.1	......	20.5	......	51	......	88.6	......	53.00
32	......	62	......	19.1	......	25.0	......	20	......	67.8	......	56.00
34	33	59	20.6	18.9	20.5	31.0	68	13	93.3	53.8	54.75	51.00
Starboard side—												
35	......	85	......	18.1	......	27.0	......	0	......	2.2	......	45.50
36	......	128	......	26.8	......	46.0	......	0	......	0	......	41.50
37	......	50	......	19.1	......	18.5	......	77	......	96.3	......	55.00
38	......	48	......	17.9	......	18.5	......	68	......	91.0	......	55.00
39	......	65	......	19.2	......	19.5	......	65	......	88.5	......	51.25
Hold 5:												
Port side—												
40	32	37	19.8	18.6	18.0	21.5	77	68	91.7	90.6	52.50	52.25
41	32	38	20.8	19.6	19.0	20.5	55	66	94.3	87.6	54.00	54.00
42	32	45	19.1	19.2	19.0	19.0	84	84	95.7	94.4	54.50	53.25
43	27	32	19.3	19.3	16.5	18.0	84	74	93.0	95.8	55.00	53.00
44	29	32	19.5	19.0	17.0	17.5	67	75	94.6	94.5	55.00	54.00
45	31	41	20.0	19.6	18.0	17.5	73	74	92.3	93.2	52.00	53.25
46	32	50	20.5	18.9	17.5	20.5	63	42	90.6	85.5	55.00	53.00
Starboard side—												
47	......	47	......	20.5	......	21.0	......	49	......	91.4	......	52.50
48	......	42	......	19.4	......	17.5	......	76	......	94.2	......	54.50
49	......	119	......	22.9	......	37.0	......	0	......	0	......	46.00
Hold 6:												
50	32	37	19.3	18.9	17 0	18 0	81	80	95.7	92.1	56.00	55.00
51	28	52	18.4	18.3	15.5	18.0	90	91	98.7	97.1	55.00	54.50

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

The top of the corn in each hold of the vessel was either below or near the water line. In holds 1, 2, and 3 there was very little change in the condition of the corn during the voyage, as shown in figure 29 and Table 20. In holds 4, 5, and 6, which contained two shaft tunnels along the bottom, the corn became badly damaged over and along the starboard tunnel. This is illustrated in figure 30. It will be seen in the cross section of hold 4 that samples Nos. 30 and 36, which were taken from the corn a short distance above the starboard tunnel, had a temperature of 132 and 128° F. and tested 36 and 46 c. c. in acidity. The corn in both samples had lost all vitality and was badly discolored. Compared to these, samples Nos. 37, 38, and 39, which were taken in the starboard tank from about the same height, but some distance away, did not exceed 65° F. in temperature and 19.5 c. c. in acidity, and sample No. 35, which was taken from directly above the tunnel, but near the surface of the corn, had a temperature of but 85° F. Sample No. 29, which was also taken from above this tunnel, but near the surface of the corn, had a temperature of 90° F. The starboard shaft tunnel, which had the two steam pipes in it, had a temperature inside the tunnel considerably higher than the temperature in the port shaft tunnel, which did not have any steam pipes in it. The corn surrounding the port shaft tunnel was "packed," moldy, and sour, and had a higher temperature than the corn a short distance away from the tunnel, but it was not hot or discolored. The same condition of damaged corn along and over the starboard shaft tunnel, as found in hold 4, was also found in holds 5 and 6, as will be seen from the cross sections of these holds. Sample No. 49, which was taken from the corn about a foot from the starboard shaft tunnel in hold 5, had a temperature of 119° F., and an acidity of 37 c. c., while sample No. 47, taken from directly above it, near the surface of the corn, had a temperature of only 47° F., and an acidity of 21 c. c., and

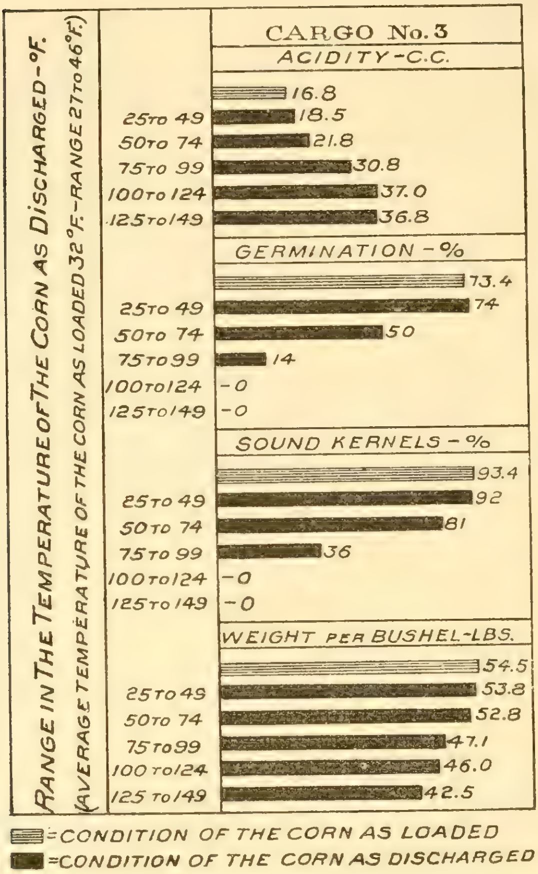


FIG. 31.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 3.)

sample No. 42, taken from the corn about a foot from the port tunnel, had a temperature of 45° F., and an acidity of only 19 c. c. Sample No. 43, which was taken from the same height in the corn, but half-way between the tunnel and the outside of the hold, had a temperature still colder, 32° F., and an acidity of only 18 c. c. Table 19 shows the total range in each factor and condition of the corn by holds as loaded and as discharged. Table 20 shows the condition of each sample taken from the corn as it was being loaded and the condition of each sample that was taken from the corn as being discharged. The correlation of temperature changes and changes in condition of the corn is illustrated in figure 31.

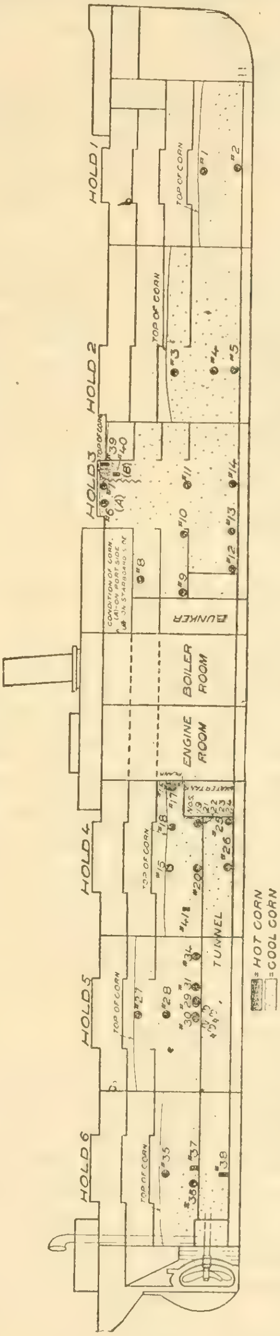


FIG. 32.—Diagram showing arrangement of the steamship and stowage of the corn in the holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 4.)

CARGO No. 4.

Cargo No. 4 consisted of 197,142 bushels of natural corn. The corn was loaded February 20 and 21, 1911. The vessel sailed February 22 and arrived at Bremerhaven on March 8, where the corn was discharged March 9 to 16. The length of the ocean voyage was 14 days. The maximum time that any of the corn was in the vessel was 24 days and the average time 20 days.

STOWAGE OF THE CORN.

The steamship had six cargo holds, as is shown in figure 32. Hold 3 was entirely filled with corn, and the remaining holds were only partly filled with corn. The vessel had two shaft tunnels running through the bottom of holds 4, 5, and 6, neither of which tunnels carried steam pipes and both of which were ventilated.

CONDITION OF THE CORN AS LOADED.

The condition of the corn as loaded is shown in Tables 21 and 22. The averages for the various factors of the corn as loaded were as follows: Moisture content 19.5 per cent, acidity 21.0 c. c., germination 69.9 per cent, sound kernels 94.0 per cent, weight per bushel 53.4 pounds. The corn at the time of loading had an average temperature of 37.6° F.

TABLE 21.—*Range in the principal factors, showing quality and condition of the corn in cargo No. 4, as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
Hold 1:	*°F.*	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
As loaded	35.0– 37.0	19.4–19.6	20.0–21.0	61.0–63.0	93.5–94.2	53.2–54.2
As discharged	39.0– 49.0	19.3–19.6	20.5–20.5	56.0–66.0	90.8–91.6	53.0–53.0
Hold 2:						
As loaded	34.0– 34.0	19.0–19.9	19.0–22.0	63.0–75.0	93.3–96.6	53.0–53.0
As discharged	39.0– 44.0	18.6–20.4	20.5–27.0	32.0–67.0	73.9–93.7	53.0–53.5
Hold 3:						
As loaded	34.0– 39.0	18.5–20.3	19.5–22.5	58.0 82.0	89.1–95.6	52.7–54.0
As discharged	40.0–118.0	18.4–38.1	17.0–49.0	78.0	93.4	48.0–53.7
Hold 4:						
As loaded	35.0– 48.0	18.9–20.7	19.5–23.0	68.0–78.0	89.7–97.2	52.2–54.2
As discharged	40.0– 79.0	18.1–20.8	19.0–39.0	12.0–61.0	48.6–91.7	48.5–54.0
Hold 5:						
As loaded	36.0– 38.0	17.6–19.7	20.0–25.0	60.0–76.0	89.6–95.4	51.5–55.0
As discharged	38.0– 65.0	17.7–20.0	18.0–24.5	48.0–77.0	82.9–94.8	45.5–53.5
Hold 6:						
As loaded	37.0– 38.0	18.8–19.0	20.0–20.0	80.0–84.0	91.5–93.9	54.0–55.0
As discharged	39.0– 60.0	18.5–19.2	18.0–21.0	64.0–86.0	89.6–91.3	52.5–53.5

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

The steamship carrying this cargo was of practically the same construction as the vessel carrying cargo No. 3, except that it did not have any steam pipes in either of its shaft tunnels. The corn was loaded to varying heights in each of the six holds, only hold 3 being entirely filled with corn. With the exception of small amounts of corn in the upper part of hold 3 and the forward part of hold 4, the corn in this cargo changed but little during the voyage and arrived in Europe in good condition. The detailed results of the analyses of the samples taken from this cargo are shown in Table 22.

Hold 1 was filled about one-third full of corn. The corn as discharged ranged from 39° to 49° F. in temperature, 20.5 c. c. in acidity, 56 to 66 per cent in germination, and 90.8 to 91.6 per cent in sound kernels.

Hold 2 was more than half-filled with corn. The corn as discharged ranged from 39° to 44° F. in temperature, 20.5 to 27 c. c. in acidity, 32 to 67 per cent in germination, and 79.9 to 93.7 per cent in sound kernels. Sample No. 3 represents a thin layer of corn at the surface which was somewhat moldy and had started to go out of condition. It tested 27 c. c. in acidity, germinated 32 per cent, and had 73.9 per cent of sound kernels. Neither of the two other samples taken from this hold lower down in the corn tested over 21 c. c. in acidity or contained less then 93.5 per cent of sound kernels.

TABLE 22.—*Condition of the corn in cargo No. 4 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

Hold and sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1:	*°F.*	*°F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Pounds.*	*Pounds.*
1...	35	39	19.6	19.6	20.0	20.5	61	56	94.2	91.6	54.25	53.00
2...	37	49	19.4	19.3	21.0	20.5	63	66	93.5	90.8	53.25	53.00
Hold 2:												
3...	34	39	19.7	20.4	21.5	27.0	63	32	96.6	73 9	53.00	53.00
4...	34	39	19.9	18.6	22.0	21.0	75	67	93.7	93.5	53.00	53.50
5...	34	44	19.0	20.0	19.0	20.5	64	59	93.3	93.7	53.00	53.00
Hold 3:												
39..	......	118	......	20.1	......	32.5	......	0	......	8.7	....	48.00
6...	34	57	20.3	19.4	22.5	23.0	70	54	95.3	91.3	53.50	51.75
7...	34	59	20.1	19.8	20.0	23.0	76	52	93.1	87.2	53.00	51.50
40..	......	118	......	....	......	29.0	......	1	......	....	....	....
8...	35	42	19.8	19.1	19.5	17.0	61	71	95.6	91.8	53.75	53.00
9...	39	59	19.3	19.4	21.0	22.0	70	55	91.4	86.6	53.50	51.25
10..	37	40	19.6	19.5	21.5	18.0	64	70	92.6	93.4	53.00	53.75
11..	36	46	19.2	19.3	19.5	18.5	82	78	92.8	92.6	54.00	52.50
12..	37	53	19.2	19.0	22.0	27.5	58	46	90.2	80.2	52.75	51.50
13..	36	49	18.5	18.4	19.5	20.0	60	65	92.6	90.6	53.25	51.75
14..	36	49	19.4	19.9	21.0	20.0	64	67	89.1	91.1	53.00	52.25
Hold 4:												
15..	43	58	18.9	18.2	22.0	25.0	78	40	96.4	87.1	51.25	51.25
17..	35	65	19.4	18.1	19.5	27.0	76	23	94.7	73.9	55.00	50.50
18..	36	40	19.7	19.4	20.5	23.5	73	53	95.2	89.5	54.00	53.00
16..	37	41	20.2	19.3	23.0	19.0	69	61	92.3	89.4	53.50	54.00
41..	......	70	......	19.0	......	22.5	......	31	......	82.5	....	50.50
19..	40	66	19.5	20.2	20.5	27.0	71	33	95.1	75.1	53.25	49.75
20..	37	53	20.1	....	22.0	23.0	69	60	94.6	91.7	53.50	52.75
21..	40	84	20.0	19.0	20.0	32.0	74	27	93.8	64.0	53.25	49.25
22..	48	81	21.0	19.0	21.0	39.0	68	26	89.7	52.7	52.75	49.50
23..	42	79	20.3	19.4	20.0	29.0	69	36	95.7	72.8	53.25	48.50
24..	48	70	20.3	20.2	19.5	39.0	72	12	93.2	48.6	52.25	51.00
25..	39	58	20.2	19.6	21.5	23.0	78	59	96.6	87.6	53.50	51.50
26..	40	53	20.7	20.8	21.0	24.0	75	61	97.2	90.3	52.75	51.25
Hold 5:												
27..	36	44	19.4	18.8	22.5	20.0	63	53	92.5	93.5	52.50	52.00
28..	38	42	19.7	20.0	22.0	19.0	71	77	91.8	93.3	51.50	45.50
29..	36	38	19.4	19.5	21.5	19.0	73	69	92.1	92.3	53.25	....
30..	37	38	18.4	19.2	25.0	23.5	60	59	95.4	88.0	54.00	52.25
31..	36	38	19.3	19.0	23.0	20.0	62	70	94.9	91.2	53.25	51.75
32..	38	62	17.8	18.7	22.5	25.0	76	55	89.6	82.9	55.00	53.50
33..	38	42	19.2	19.0	20.0	18.0	73	76	92.2	94.8	48.00	53.00
34..	37	65	17.6	17.7	21.5	24.5	74	48	95.0	92.6	54.00	....
Hold 6:												
35..	37	39	18.8	18.5	20.0	19.0	80	86	91.5	90.8	54.00	53.00
36..	38	59	19.0	19.2	20.0	18.0	84	74	93.9	91.3	55.00	53.50
37..	38	60	......	19.0	......	20.0	......	72	......	89.6	....	52.50
38..	37	57	......	18.7	......	21.0	......	64	......	90.0	....	52.50

Hold 3 was entirely filled with corn. A small amount of the corn along the starboard side at the top was hot and damaged, as is shown in figure 33. It will be seen that samples Nos. 39 and 40 taken from this hot corn each had a temperature of 118° F. and an acidity of 32.5 c. c. in the first and 29 c. c. in the second sample. None of the kernels in sample No. 39 would sprout, and only 1 per cent of sample No. 40 had any vitality. There was a steam pipe opposite this hot corn which ran along the deck close to the hatch. This steam pipe carried live steam to the winches along the deck and was under pressure of steam during the first few days after the hold was filled with corn and again for a few days at the end of the voyage before the corn in this hold was discharged. Compared with the hot corn, samples Nos. 6 and 7, taken from the corn near the surface on the port side of the hatch, had a temperature of but 57° and 59° F., an acidity of only 23 c. c. each, and a germination of 54 and 52 per cent, respectively. None of the remaining samples taken from the hold had a temperature higher than 59° F.

Hold 4 was about half filled with corn. In the lower part of the hold there was a water tank, extending across the hold against the forward bulkhead, opposite the engine room. The corn stowed immediately against this tank was heating at the end of the voyage but was only slightly discolored. That portion of the corn next to the tank which surrounded the shaft tunnels was more damaged than the corn located toward the sides of the hold. The averages for the samples taken from the corn located at a height even with the top of the shaft tunnels are shown in Table 23. It will be seen that those samples which represented the corn stowed next to the water tank had on an average a higher temperature by 23° F., more acidity by 10.3 c. c., was poorer in germination by 33.2 per cent, had less sound kernels by 29 per cent, and had a lower test weight by 3.1 pounds per bushel than sample No. 20, which represents corn stowed some distance back from the tank and away from the shaft tunnels.

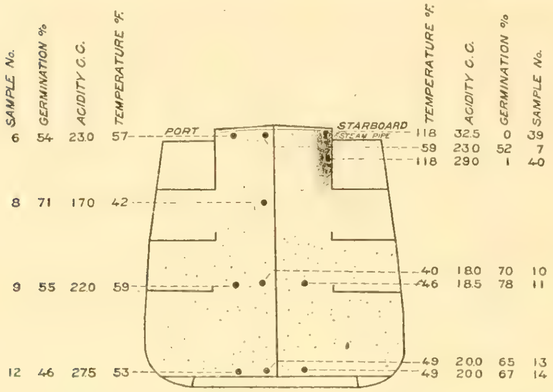


FIG. 33.—Cross-section of hold 3, cargo No. 4, showing location of heat-damaged corn in the upper part of the hold opposite a steam pipe on the deck. Heavy shading represents heat-damaged corn as discharged. (Cargo No. 4.)

TABLE 23.—*Averages for the samples taken from the corn at tunnel height.*

Samples located at tunnel height hold 4.	Temperature.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° F.	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Against tank (Nos. 21, 22, 23, 24)[1]	76	33.3	26.8	62.7	49.60
Free from tunnels and tank, No. 20	53	23.0	60.0	91.7	52.75

[1] Data represent averages for these samples.

That part of the corn at the surface (in hold 4), which was located next to the engine-room bulkhead over the water tank, was out of condition, being sour, moldy, and "packed." Compared to the condition of the corn at the surface, which was located back some distance from the bulkhead, the corn stowed against the engine-room bulkhead had, on an average, a higher temperature by 21° F., a higher acidity by 4.8 c. c., and lower germination by 25.5 per cent, less sound kernels by 8.9 per cent, and a lower test weight per bushel by 2.6 pounds.

Hold 5 was nearly three-quarters filled with corn. In this hold the corn ranged from 38° to 65° F. in temperature, 18 to 24.5 c. c. in acidity, 48 to 77 per cent in germination, and 82.9 to 94.8 per cent in sound kernels. The corn was in good condition when discharged except for a small amount located near the shaft tunnels, which was slightly out of condition. Of the corn located at the same height as the top of the tunnels, that which was stowed on and between the tunnels had, on an average, a higher temperature by 6° F., a higher acidity by 4 c. c., a lower germination by 11.2 per cent, less sound kernels by 16.1 per cent, and a lower test weight per bushel by 0.5 pound than the corn stowed half way between the tunnels and the outside of the hold, as shown in Table 23.

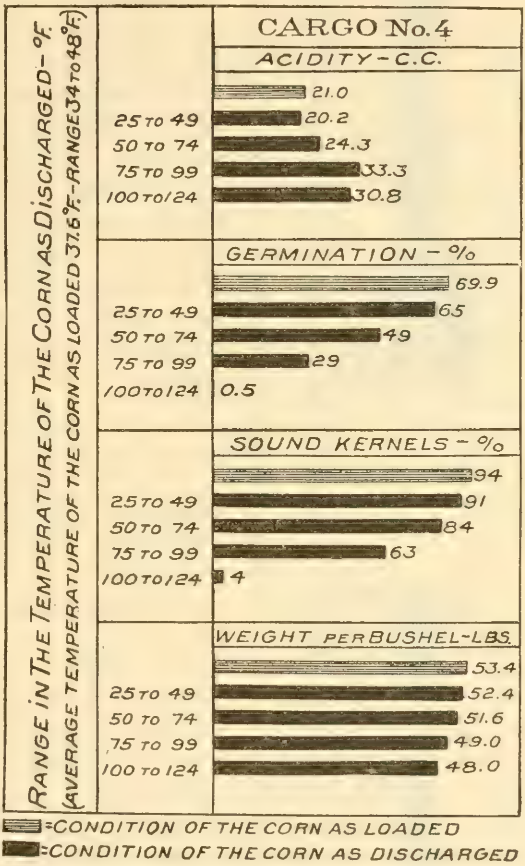


FIG. 34.—Correlation of the temperatures and condition of the corn as loaded and as discharged. (Cargo No. 4.)

Hold 6 was about one-half filled with corn. The corn as discharged ranged from 39 to 60° F. in temperature, 18 to 21 c. c. in acidity, 64 to 86 per cent in germination, and 89.6 to 91.3 per cent in sound kernels. The condition of the corn in this hold, like that in hold 5, was sound when discharged except that a small amount of corn stowed next to the shaft tunnels was slightly out of condition. Table 22 shows the condition of each sample taken as the cargo was being loaded and as the cargo was being discharged.

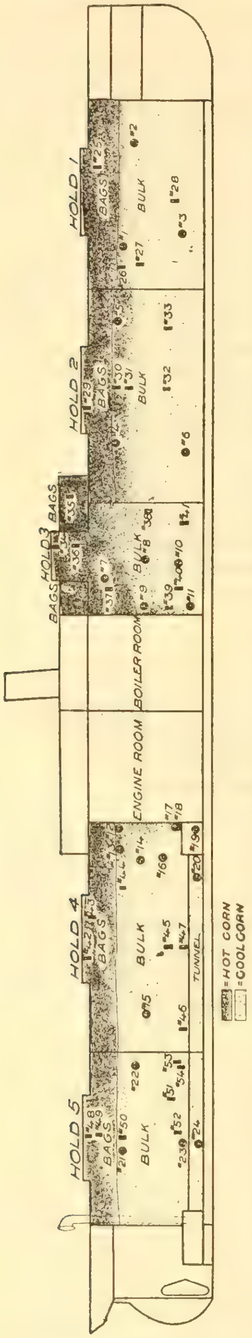


FIG. 35.—Diagram showing arrangement of the steamship and stowage of the corn in holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 5.)

The correlation of temperature changes and changes in condition of the corn is illustrated in figure 34.

CARGO No. 5.

Cargo No. 5 consisted of 185,571 bushels of natural corn. The corn was loaded April 20 to 24, 1911. The steamship sailed April 25 and arrived at Dunkirk, France, May 13, where the corn was discharged from May 18 to 27. The length of the ocean voyage was 18 days. The maximum time that any of the corn was in the vessel was 38 days and the average time 31 days. This cargo was not accompanied to Europe, but was thoroughly sampled at time of loading in America and again at time of discharge in France.

STOWAGE OF THE CORN.

The steamship had five cargo holds, as shown in figure 35. This shipment was a full cargo, each hold being entirely filled with corn.

CONDITION OF THE CORN AS LOADED.

The condition of the corn as loaded is shown in Tables 24 and 25. The averages for the various factors of the corn as loaded were as follows: Moisture content 19.2 per cent, acidity 24.4 c. c., germination 59.1 per cent, sound kernels 95.2 per cent, and weight per bushel 53.4 pounds. The corn at the time of loading had an average temperature of 38° F.

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

As already stated, the steamship carrying cargo No. 5 had each of its five holds entirely filled with corn. As the cargo was being discharged in Europe, it was found that the corn in the upper portion of each hold was badly damaged. This damaged condition is illustrated in figure 35. As will be seen in Table 24, the temperature of the corn as discharged ranged from 59° to 138° F. in hold 1, 61 to 142° F. in hold 2, 53 to 140° F. in hold 3, 59 to 140° F. in hold 4, and 64 to 138° F. in hold 5. The temperature in a general way was the highest at the surface of the corn and decreased toward the bottom. It will be seen in figure 36 and Table 25 that all of the corn in the lower portion of the holds was not hot, but the corn was very poor in condition.

TABLE 24.—*Range in the principal factors showing quality and condition of the corn in cargo No. 5, as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
Hold 1:	*°F.*	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
As loaded	[1]38.0	19.4–19.8	23.4–28.0	45.0–63.0	85.7–95.9	53.0–53.5
As discharged	59.0–138.0	....	28.3–48.6	0–52.0	0–90.2	48.5–53.5
Hold 2:						
As loaded	[1]38.0	18.6–19.7	19.8–27.4	56.0–72.0	92.0–97.0	54.0–54.5
As discharged	61.0–142.0	....	25.4–69.3	0–36.0	0–73.9	48.0–53.3
Hold 3:						
As loaded	[1]38.0	18.8–19.7	22.6–28.6	45.0–62.0	91.0–96.0	52.8–53.8
As discharged	53.0–140.0	....	29.1–72.7	0–62.0	0–69.2	46.5–53.5
Hold 4:						
As loaded	[1]38.0	16.6–19.6	21.2–25.4	56.0–74.0	94.1–98.8	53.0–53.8
As discharged	59.0–140.0	....	23.7–67.1	0–64.0	0–87.2	47.0–53.3
Hold 5:						
As loaded	[1]38.0	19.2–20.1	23.2–24.4	48.0–65.0	94.8–98.2	52.5–53.5
As discharged	64.0–138.0	....	26.7–71.4	0–44.0	0–68.6	46.8–51.5

[1] Average temperature for the cargo.

TABLE 25.—*Condition of the corn in cargo No. 5 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

Hold and sample No.	Temperature.		Moisture content as loaded.	Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.		As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1:	*°F.*	*°F.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
25	[1]38	138	......	......	36.4	......	0	......	0	....	48.50
1		135	19.4	28.0	48.6	45	0	85.7	0	53.00	49.25
26		85	......	......	38.7	......	24	......	32.0	....	51.50
2		75	19.8	26.2	39.7	53	36	93.6	16.4	53.25	51.00
27		61	......	......	32.8	......	52	......	72.4	....	52.25
3		63	19.6	23.4	30.8	63	34	95.9	57.3	53.50	53.25
28		59	......	......	28.3	......	36	......	90.2	....	52.50
Hold 2:											
29	[1]38	138	......	......	65.4	......	0	......	0	....	48.00
4		133	19.7	27.4	52.4	56	0	92.0	0	54.25	48.50
5		139	18.9	27.2	52.7	60	0	93.2	0	54.50	51.00
30		142	......	......	69.3	......	0	......	0	....	48.50
31		115	......	......	34.0	......	0	......	0	....	52.00
32		82	......	......	40.7	......	28	......	62.8	....	50.50
33		91	......	......	39.0	......	36	......	55.0	....	50.00
6		61	18.6	19.8	25.4	72	26	97.0	73.9	54.00	53.25

[1] Average for the hold.

TABLE 25.—*Condition of the corn in cargo No. 5 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom*—Continued.

Hold and sample No.	Temperature.		Moisture content as loaded.	Acidity.		Germination.		Sound kernels		Weight per bushel.	
	As loaded.	As discharged.		As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
	° F.	° F	P. ct.	c. c.	c. c.	P. ct.	P. ct.	P. ct.	P. ct.	Lbs.	Lbs.
Hold 3:											
34	[1]38	138			72.7		0		0		46.50
35		131			59.4		0		0		48.00
36		136			58.2		0		0		50.50
7		129	19.7	22.6	71.0	62	0	93.3	0	52.75	48.00
37		140			60.7		0		0		48.50
8		122	19.7	28.6	49.2	50	6	94.9	12.5	53.50	50.00
9		108	19.6	26.0	57.2	45	0	94.4	0	53.50	50.50
38		95			24.3		62		69.2		52.50
39		90			43.8		2		16.3		49.50
10		95	18.8	25.8	32.4	45	38	96.0	50.6	53.75	52.50
40		53			29.1		28		66.1		53.50
41		71			31.0		18		66.6		52.00
11		81	18.8	24.0	41.6	56	6	91.0	40.5	53.25	51.50
Hold 4:											
42	[1]38	140			67.1		0		0.7		47.00
43		131			57.6		6		5.8		49.50
12		104	19.4	25.2	61.4	63	0	97.6	0	53.75	47.50
13		127	18.9	24.2	29.0	57	0	95.9	0	53.75	48.50
44		77			42.2		30		55.4		51.50
14		77	16.9	23.8	29.9	66	38	94.1	78.6	53.25	52.00
15		74	19.4	25.4	40.2	63	26	97.9	60.1	53.75	51.50
16		95	19.6	23.0	32.6	56	12	98.8	45.4	53.00	51.00
45		59			23.7		64		87.2		53.00
17		72	19.6	22.8	25.4	61	38	97.0	56.7	53.25	52.25
18		72	16.6	21.2	27.9	74	34	95.0	75.6	53.25	52.00
46		85			31.9		32		50.2		51.00
47		68			25.9		52		79.4		53.25
19		65	19.2	22.8	30.4	74	30	96.4	73.7	53.25	53.25
20		63	18.9	22.8	36.3	71	10	97.5	64.5	53.50	51.50
Hold 5:											
48	[1]38	138			57.7		0		0		46.75
49		115			58.0		4		0		49.50
21		97	19.2	24.4	34.0	53	20	94.8	42.3	53.50	51.50
50		69			26.7		28		58.6		51.50
22		101	20.0	24.4	45.0	48	10	98.2	16.2	52.50	51.00
51		77			36.8		28		68.6		51.00
52		77			71.4		16		57.0		51.00
53		93			41.9		16		42.1		49.50
54		77			41.4		44		54.5		50.50
23		81	20.1	23.2	48.7	60	18	96.7	45.9	52.50	51.00
24		64	20.1	24.4	40.5	65	21	97.4	48.8	52.75	51.50

[1] Average for the hold.

As is seen from cross section of hold 1, in figure 36, the corn in this hold as discharged ranged in temperature from 138° F. near the surface to 59° F. in the lower part of the hold. The heat-discolored corn extended from the surface to a little over one-fourth down in the hold. The two samples taken from the heat-discolored corn, sample No. 25 from a short distance below the surface and sample No. 1 from the lower portion of the hot corn, had temperatures of 138° and 135° F. and tested 36.4 and 48.6 c. c. in acidity. None of the kernels in either sample would germinate. Only one sample taken from the corn that was not heat-discolored tested under 30 c. c. in acidity. This sample, No. 28, was taken about 7 feet from the bottom of the hold. It had a temperature of 59° F., tested 28.3 c. c. in acidity and germinated 36 per cent, but sample No. 3, taken from still lower in the hold, had a temperature of 63° F., and tested 30.8 c. c. in acidity, with a germination of 34 per cent. Sample No. 26, taken from the upper part of the corn that was not heat discolored, had a temperature of 85° F., tested 38.7 c. c. in acidity, and germinated 24 per cent.

The temperature of the corn in hold 2 as discharged ranged from 142° F. in the heat-discolored corn in the upper part of the hold to 61° F. in the lower part of the hold, as shown in figure 36. All of the corn in the upper part of the hold was heat-discolored. None of the kernels from the samples taken from the heat-discolored corn sprouted in the germination test, and the samples taken from the cooler corn in the lower half of the hold tested low in germination. All of the samples taken from the various parts of the hold,

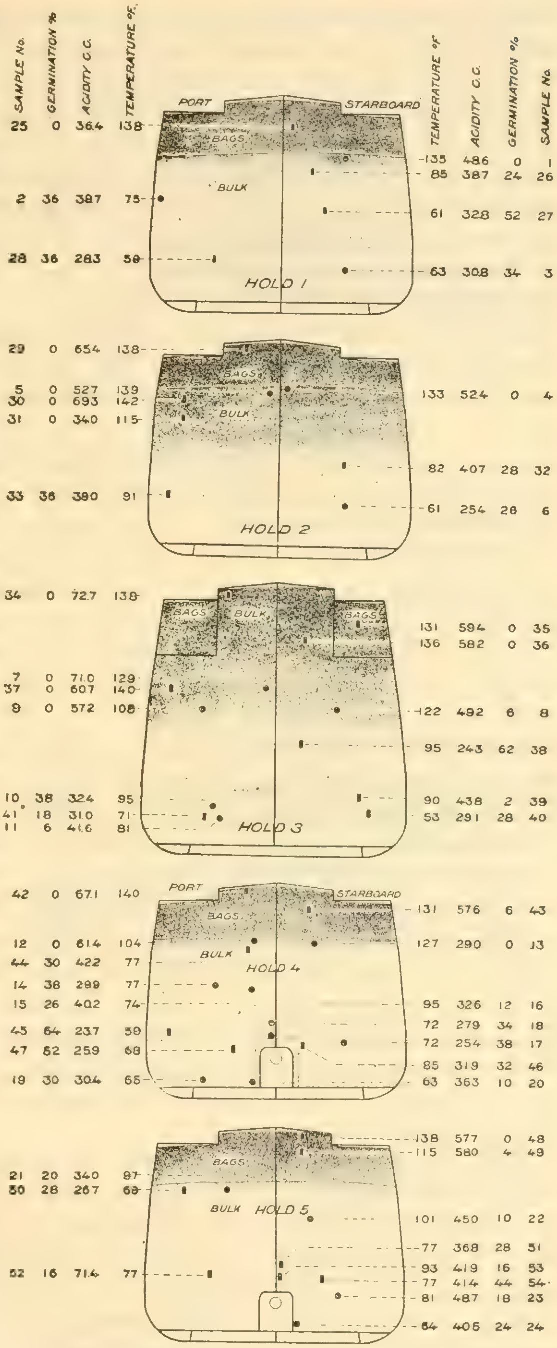


FIG. 36.—Cross-sections, holds Nos. 1 to 5, inclusive, showing the locations from which the samples were taken from the corn. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 5.)

with one exception, tested over 30 c. c. in acidity. Sample No. 6, taken about 7 feet from the bottom, tested 25.4 c. c. in acidity, but sample No. 33, taken about the same distance from the bottom but on the opposite side of the hold, tested 39 c. c. in acidity.

Hold 3 was one deck higher than the remaining holds in the vessel. In this hold the heat-discolored corn extended from the surface to about halfway down in the hold. The temperature of the corn, as is shown in figure 36, ranged from 140° F. in the heat-damaged corn in the upper part of the hold to 53° F. near the bottom on the starboard side. Only one sample, No. 8, in the heat-discolored corn, showed any vitality; it germinated 6 per cent. Two samples taken from the lower part of the hold, Nos. 39 and 11, tested 2 per cent and 6 per cent in germination. Both were high in acidity, testing 43.8 c. c. and 41.6 c. c. in acidity. Two samples, Nos. 38 and 40, taken from the lower half of the hold, tested under 30 c. c. in acidity. Sample No. 38, taken from the upper part of the corn that was not heat-discolored, tested 24.3 c. c. in acidity and germinated 62 per cent, while sample No. 40 taken about 5 feet from the bottom on the starboard side tested 29.1 c.c. in acidity and germinated 28 per cent. Sample No. 34, taken from the corn at the surface, showed the highest acidity test. This sample had a temperature of 138° F., tested 72.7 c. c. in acidity, and contained no corn that would germinate.

As will be seen from figure 36, the temperature of the corn in hold No. 4, as discharged, ranged from 140° F. at the surface to 59° F. in the lower part of the hold. Only one sample, No. 43, taken from the heat-discolored corn in the upper one-fourth of the hold showed any vitality; it germinated 6 per cent, tested 57.6 c. c. in acidity, and had a temperature of 131° F. Sample No. 42, taken from the corn at the surface, had a temperature of 140° F., tested 67.1 c. c. in acidity, and had no corn that would germinate. The heat-discolored corn extended about one-fourth the distance down in the hold. The corn in contact with the shaft tunnel in the lower part of the hold was more sour, packed, and moldy than that surrounding it, but it was not heat-discolored. The same condition extended along the shaft tunnel in hold 5.

The condition of the corn in hold 5 was very similar to that in hold 4. The heat-discolored corn extended about one-fourth the distance down from the surface, and the remainder of the corn in the hold was very poor in condition. Sample No. 48, at the surface, had a temperature of 138° F., tested 57.7 c. c. in acidity, and had lost all vitality. Sample No. 24, taken from the bottom, had a temperature of 64° F., tested 40.5 c. c. in acidity, and germinated 24 per cent. The condition of the corn that was not heat-discolored varied greatly at different positions of stowage. Sample No. 50, which was taken from the bulk corn just under the heat-damaged position, had a temperature of 69° F., tested 26.7 c. c. in acidity, and germinated 28 per cent, while sample No. 22, taken from the corn nearly halfway down the hold, had a temperature of 101° F., tested 45 c. c. in acidity, and germinated 10 per cent. Sample No. 50 was the only one taken from the corn in this hold which tested under 30 c. c. in acidity, and only two other samples, Nos. 21 and 51, tested under 40 c. c. in acidity. Table 26 shows the average condition of the corn in the cargo as loaded compared with the average condition of the corn which was not heat damaged and of that which was heat discolored, as discharged, the average being based upon the samples that were taken from the corn, the positions of which are illustrated in the diagrams in figures 35 and 36.

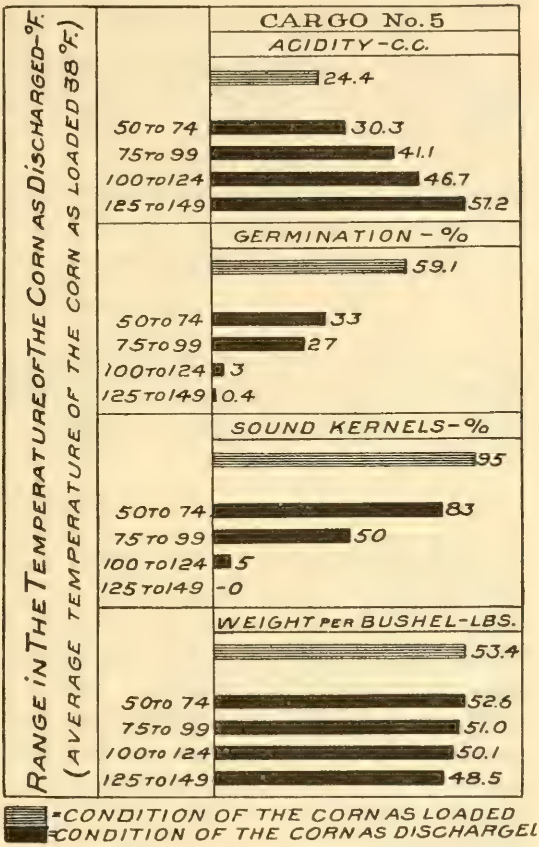


FIG. 37.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 5.)

TABLE 26.—*Showing the average condition of the corn as loaded, the average condition of the corn as discharged, and the average condition of the heat-damaged corn as discharged.*

Stage.	Temperature.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	°F.	*c.c.*	*Per cent.*	*Per cent.*	*Pounds.*
Average as loaded	38	24.4	59.1	95.2	53.4
Average of cool corn as discharged	77	35.6	29.0	56.8	51.6
Average of heat-damaged corn as discharged	130	55.9	1.0	1.0	48.8

It will be seen in the table that there was considerable deterioration during the voyage in the corn that did not become heat-discolored and that the corn which did become heat-discolored was very badly damaged.

The correlation of temperature changes and changes in the condition of the corn is illustrated in figure 37.

CARGO No. 6.

Cargo No. 6 consisted of 200,270 bushels of corn, part of which was natural corn and part of which was artificially dried corn. It was loaded March 21 to 27, 1911. The steamship sailed March 28 and arrived in Rotterdam, Holland, April 17, where the corn was discharged from April 18 to April 22. The length of the ocean voyage was 20 days; the maximum time any of the corn was in the vessel was 32 days; and the average time was 27 days.

STOWAGE OF THE CORN.

The steamship had five cargo holds, as is shown in figure 38. This shipment was a full cargo, each hold being entirely filled with corn. Holds 1, 2, 3, and 5 were filled with natural corn, and hold 4 contained artificially dried corn.

CONDITION OF THE CORN AS LOADED.

The condition of the corn as loaded is shown in Tables 27, 28, and 29. It will be noted from Table 28 that, on an average, the dried corn in hold 4 had a temperature of 50° F., was relatively high in acidity (27 c. c.) and low in germination (45.6 per cent), but had a low moisture content (15.6 per cent). Sound kernels, as determined by mechanical analysis, averaged 92.5 per cent. The natural corn in the remaining holds of the cargo had an average temperature of 42° F., acidity of 24.3 c. c., germination of 65.3 per cent, and 95.7 per cent of sound kernels, but was high in moisture content, which averaged 20.2 per cent.

TABLE 27.—*Range in the principal factors showing quality and condition of the corn in cargo No. 6 as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° F.	*Per cent.*	*c.c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 1:						
As loaded	41.0- 50.0	19.7-20.6	22.5-24.2	63.0-76.0	93.7-96.3	52.5-53.8
As discharged	42.0- 53.0	19.0-20.0	26.3-41.4	16.0-55.0	53.4-85.8	49.5-51.0
Hold 2:						
As loaded	39.0- 49.0	19.2-20.4	21.9-27.2	52.0-73.0	95.4-97.7	53.0-53.3
As discharged	45.0-140.0	15.0-27.0	24.8-65.2	0-50.0	3.2-93.7	46.0-52.0
Hold 3:						
As loaded	37.0- 40.0	20.1-20.9	22.9-24.4	61.0-82.0	94.0-98.0	52.0-53.0
As discharged	44.0-140.0	17.6-20.4	22.8-59.5	0-55.0	1.5-76.1	45.5-51.0
Hold 4:						
As loaded	43.0- 56.0	14.7-16.3	23.2-31.0	24.0-61.0	86.1-96.5	53.0-54.8
As discharged	50.0- 85.0	14.4-16.2	25.5-32.7	7.0-52.8	57.9-95.6	52.0-53.5
Hold 5:						
As loaded	40.0- 44.0	19.7-20.9	22.4-28.6	56-0-73.0	93.9-97.1	52.0-53.5
As discharged	44.0-120.0	18.8-21.0	22.9-54.9	5.0-66.0	35.3-97.3	47.5-52.3

TABLE 28.—*Average condition of the dried corn and of the natural corn in cargo No. 6 as loaded.*

Kind of corn and where stowed.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° F.	*Per cent.*	*c.c.*	*Per cent.*	*Per cent.*	*Pounds.*
Dried corn, hold 4	50	15.7	27.0	45.6	92.5	53.91
Natural corn, holds 1, 2, 3, and 5	41	20.2	24.3	65.3	95.7	53.00

TABLE 29.—*Condition of the corn in cargo No. 6, natural corn, as loaded, and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

Hold, kind of corn, and Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1, natural corn:	*° F.*	*° F.*	*P. ct.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
1	45	53	20.4	19.0	22.5	26.3	61	55	93.7	85.8	53.00	50.50
2	41	......	20.4	......	......	......	......	......	96.0	......	52.50	......
3	50	......	19.7	......	......	......	......	......	95.1	......	53.25	......
4	44	50	20.6	20.0	23.5	39.3	61	16	94.7	53.4	53.25	50.00
5	41	42	20.2	19.5	22.9	30.8	63	26	94.8	69.5	53.25	......
6	44	49	20.6	19.7	21.2	30.2	76	26	94.0	61.4	53.75	51.00
7	41	45	19.9	19.8	23.8	41.4	72	19	96.3	62.5	53.00	49.50
Hold 2, natural corn:												
8	......	140	......	15.0	......	65.2	......	6	......	12.1	......	46.75
9	40	50	20.1	19.6	23.5	33.7	61	46	95.4	80.4	53.00	50.75
10	49	57	19.8	19.8	22.9	47.9	66	16	97.7	65.6	53.25	50.50
11	......	100	......	27.0	......	48.7	......	0	......	10.8	......	......
12	......	90	......	......	......	56.3	......	6	......	59.0	......	......
13	......	130	......	20.2	......	57.4	......	0	......	3.2	......	46.00
14	39	49	19.2	19.0	27.2	24.8	66	50	96.8	93.7	53.25	52.00
15	40	45	20.4	19.8	25.5	31.5	52	26	96.7	53.1	53.00	......
16	46	93	20.1	19.4	21.9	38.7	73	22	96.1	55.9	53.00	50.50
Hold 3, natural corn:												
17	40	98	20.4	20.4	22.9	42.2	68	18	97.4	42.6	53.00	49.50
18	40	140	20.9	17.6	24.2	59.5	62	0	94.0	1.5	52.00	45.50
19	......	138	......	......	......	48.6	......	0	......	3.9	......	......
20	40	130	20.3	18.6	23.4	56.2	61	0	95.7	8.3	53.00	50.50
21	38	51	20.1	19.7	23.3	35.0	78	28	95.6	50.8	53.00	50.00
22	37	44	20.1	19.4	24.0	22.8	82	55	98.0	76.1	53.00	51.00
Hold 4, dried corn:												
23	53	80	15 5.	16.0	24.4	29.7	48	29	94.4	65.7	54.75	52.50
24	54	54	16.0	15.4	31.0	32.7	47	46	88.4	85.7	54.50	53.50
25	51	64	15.5	14.8	......	30.5	44	29	86.1	63.9	54.00	53.50
26	......	80	......	......	......	26.6	......	7	......	63.0	......	......
27	48	53	16.0	14.4	26.8	27.6	58	52	94.9	95.6	54.25	53.50
28	54	56	16.3	16.2	23.2	27.3	56	42	96.5	75.7	54.50	53.50
29	50	50	16.0	15.3	27.6	29.8	55	35	92.7	75.3	54.25	52.50
30	56	55	16.2	15.6	23.6	26.4	61	50	95.4	90.6	54.75	53.50
31	53	66	15.7	14.6	25.9	25.5	36	33	94.9	91.8	53.50	52.50
32	49	51	16.3	15.0	29.3	25.6	58	52	87.1	89.3	54.00	52.50
33	......	85	......	......	......	31.7	......	28	......	57.9	......	......
34	50	77	16.0	......	26.2	28.7	44	21	95.1	76.3	53.00	52.00
35	43	50	14.7	15.0	29.6	30.1	24	32	92.7	87.3	53.25	52.00
36	49	55	15.0	15.2	27.6	27.0	39	35	91.9	88.8	53.25	52.00
37	53	61	15.3	15.4	26.9	29.9	36	28	92.7	91.0	53.25	52.00
38	48	51	15.2	......	29.4	29.2	32	18	92.3	79.8	53.50	52.00
Hold 5, natural corn:												
39	41	65	20.5	20.4	28.6	43.8	66	12	97.1	58.4	52.50	49.00
40	41	55	19.6	19.0	26.9	25.8	57	55	94.8	91.0	53.50	52.00
41	42	55	20.7	20.0	22.0	28.3	60	35	95.1	81.0	53.50	51.00
42	......	120	......	21.0	......	49.0	......	10	......	35.3	......	47.50
43	41	50	20.2	18.8	25.6	37.1	56	33	94.0	77.0	52.75	51.25
44	42	47	20.5	19.7	25.3	30.7	61	31	95.9	65.3	53.25	50.50
45	44	70	20.1	19.8	27.8	54.9	62	15	96.1	45.4	52.50	49.25
46	41	54	20.1	19.6	24.1	27.3	58	66	96.1	97.3	53.25	51.00
47	41	44	20.9	19.6	23.0	25.6	63	35	96.8	55.7	52.75	52.25
48	40	47	20.3	18.8	22.4	22.9	73	65	93.9	87.9	53.50	51.50
49	40	44	19.9	18.9	25.2	48.7	69	5	96.0	45.8	52.00	51.25

From this it is seen that although the tests for acidity, germination, and sound kernels showed the dried corn to be poor in quality, its moisture content was lower by 4.5 per cent than natural corn.

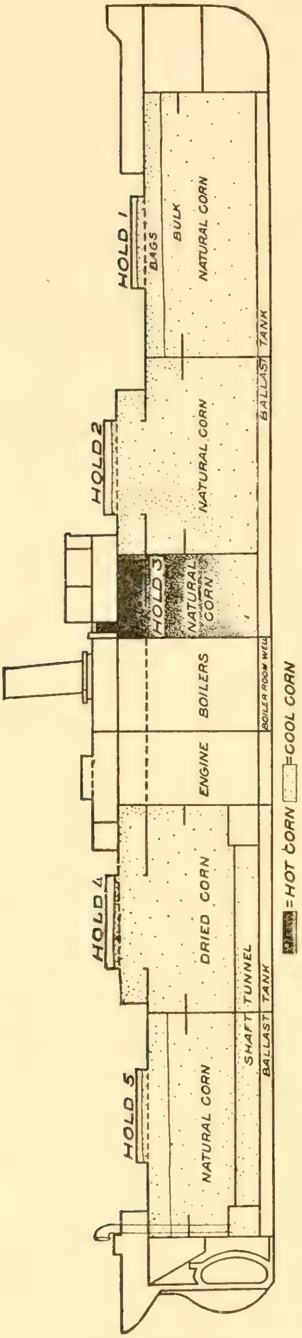


FIG. 38.—Diagram showing arrangement of the steamship and stowage of the corn in holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 6.)

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

During the voyage the temperature of the corn in various positions of stowage was recorded each day that the weather permitted. Some of the thermometers were read before the vessel sailed, and some were read for some days after the steamship arrived at its port in Europe. The location of the various thermometers and the changes in temperature at those positions are shown in figures 39 to 46, inclusive. The maximum temperatures found in the corn as discharged were 53° F. in hold 1, 140° F. in hold 2, 140° F. in hold 3, 85° F. in hold 4, and 120° F. in hold 5. These were higher than the maximum temperatures of the corn as loaded by 3° F., 91° F., 100° F., 29° F., and 76° F., in holds 1 to 5, respectively. Hold 3, however, was the only one containing any large amount of heat-damaged corn.

In hold 1 the temperature of the corn in various positions of stowage changed but little during the voyage, except along the sides of the holds, as shown by the temperature records in figure 39. As is shown in Table 29, each sample that was placed in a wire container as the cargo was loaded tested lower in quality at the end of the voyage than at the beginning of the voyage in every factor except moisture content. Only one sample, No. 1, tested under 30 c.c. in acidity. This sample was taken from the bagged corn a short distance under the surface and tested 26.3 c.c. in acidity, 55 per cent in germination, 85.8 per cent in sound kernels, and 50.5 pounds in test weight per bushel. Sample No. 7, taken from near the bottom of the hold tested 41.4 c. c. in acidity, 19 per cent in germination, 62.5 per cent in sound kernels and 49.5 pounds in test weight per bushel. The corn at the surface and along the sides of the hold for a short distance down from the top was somewhat sour, moldy, and packed.

In hold 2 some of the corn became badly heat damaged. This damaged corn was found in uneven spots on the starboard side near the after part of the hold and extended from the surface to nearly halfway down in the hold. There was also a small portion that was damaged along the forward bulkhead halfway down in the hold. The temperature of the corn as discharged from this hold ranged from 45° to 140° F. Sample No. 8, taken from the heat-damaged corn just under the top deck on the starboard side, had a temperature of 140° F., and tested 65.2 c. c. in acidity and 6 per cent in germination, while samples Nos. 9 and 10, taken from near the same height in the hold but near the shifting boards in the center, had temperatures of 50° and 57° F. and tested 33.7 and 47.9 c. c. in acidity and 46 and 16 per cent in germination, respectively. Sample No. 13, taken from the heat-damaged corn, 15 feet below the surface, had a temperature of 130° F., tested 57.4 c. c. in acidity, and no kernels sprouted in a germination test. Sample No. 11, taken from near the outside wall of the hold on the starboard side, had a temperature

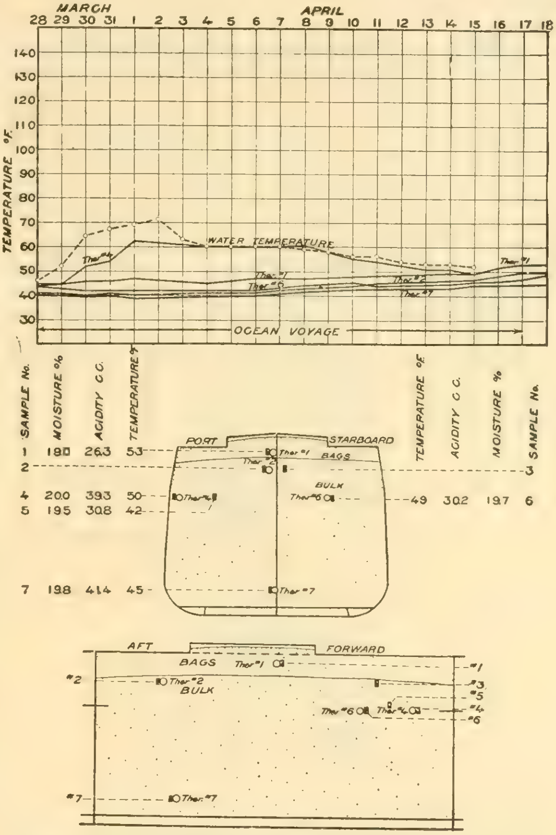


FIG. 39.—Hold 1: Temperature records of electrical resistance thermometers; location of the thermometers in the hold; and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 6.)

of 100° F., tested 48.7 c. c. in acidity, and none of it would germinate. Sample No. 14, taken from about the same height in the corn as sample No. 13, had a temperature of but 49° F., tested 24.8 c. c. in acidity, and germinated 50 per cent. Sample No. 16, taken from near the bottom on the starboard side had a temperature of 93° F., tested 38.7 c. c. in acidity, and germinated 22 per cent. The temperature record for this sample, in figure 40 shows that its temperature was 46° F. when loaded and that from March 28 to April 7 there was but little change, but from then on the temperature increased until it reached 93° F. when discharged. As will be seen in Table 29, only one sample, No. 14, tested under 30 c. c. in acidity at the time of discharge.

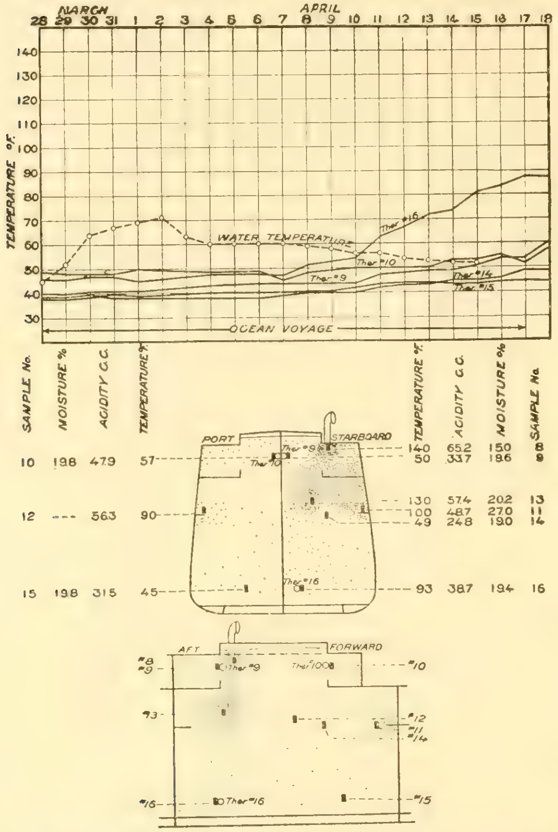


Fig. 40.—Hold 2: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 6.)

Hold 3 was one deck higher than hold 1, and had a "feeder" rounding one more deck above that. This hold was located just forward of the boiler room. Fully three-fourths of the corn as discharged was badly heat-damaged. The temperature of the corn in this hold at the time of discharge ranged from 44° to 140° F., which was greater by 7 degrees than the minimum and by 100 degrees than the maximum temperatures of the corn when loaded. Thermometer No. 18, which was located in the "feeder" about 4 feet below the surface of the corn, registered an increase in temperature from the very beginning of the voyage. The maximum temperature recorded during the voyage was 144° F., on April 15, after which there was a slight decrease. The corn surrounding this thermometer had a temperature of over 120° F. for 10 days before it was discharged. It will be noted that the temperature increased from 40° to 100° F. during the first 10 days of the ocean voyage. Thermometer 17, which was also located in the "feeder," at about the same height as thermometer 18, but next to the bulkhead separating the corn from the ventilated coal bunker, indicated a much slower increase in temperature. On April 8, 11 days after sailing, thermometer 18 indicated a temperature of 120° F.; on April 15 the temperature had increased to 144° F. Thermometer 19, located in the port side a little over halfway down from the surface of the corn, indicated an increase of 30° F. during the first 10 days and 63° F. during the last 11 days of the voyage, a total of 93° F. for the whole voyage. Temperature records for thermometers 21 and 22, located a few feet from the bottom of the hold, show that there was but little change in temperature in these places of stowage. Samples Nos. 18, 20, and 22, which were attached to thermometers of the same numbers, had temperatures of 140°, 130,° and 44° F., when discharged, and tested 59.5, 56.2, and 22.8 c. c. in acidity. Samples Nos. 18 and 20 had lost all vitality, but sample No. 22 germinated 55 per cent. Only one sample in this hold at the time of discharge tested under 33 c. c. in acidity.

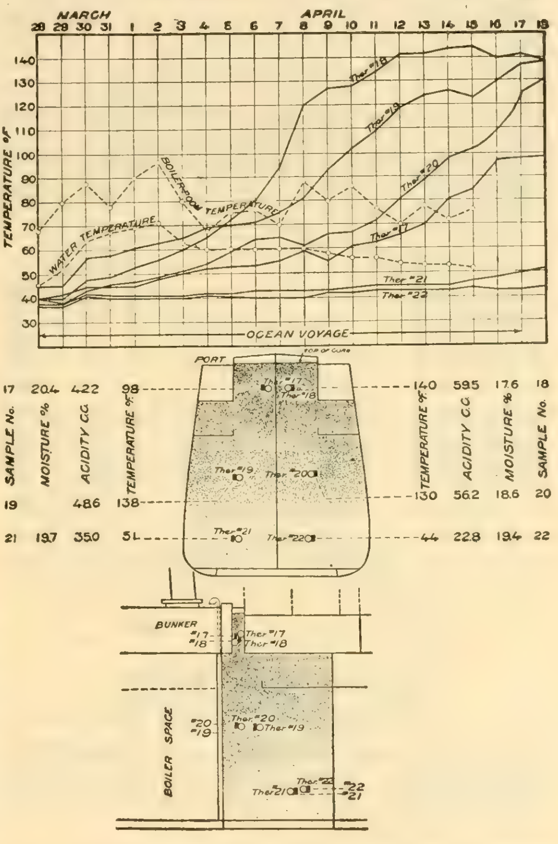


FIG. 41.—Hold 3: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 6.)

Hold 4 was one deck higher than holds 1 and 5. It was located just aft of the engine room and had a shaft tunnel in the bottom which continued through hold 5. The dried corn in this hold changed very little in temperature during the voyage, as is shown in Table 29 and figure 42. The temperature record for thermometer 23 shows that the corn at the surface near the engine room bulkhead increased 27° F. and had a temperature of 80° F. at the end of the voyage, while the temperature of the corn at the same height in the after part of the hold was the same when discharged as when loaded, as shown by the temperature record for thermometer 24. The corn stowed next to the engine-room bulkhead about 6 feet from the bottom, increased 8 degrees, and the corn stowed at the same height in the after part of the hold increased 7 degrees, as is shown by the records for thermometers 35 and 37. The effect of the engine heat on the corn is shown in Table 30.

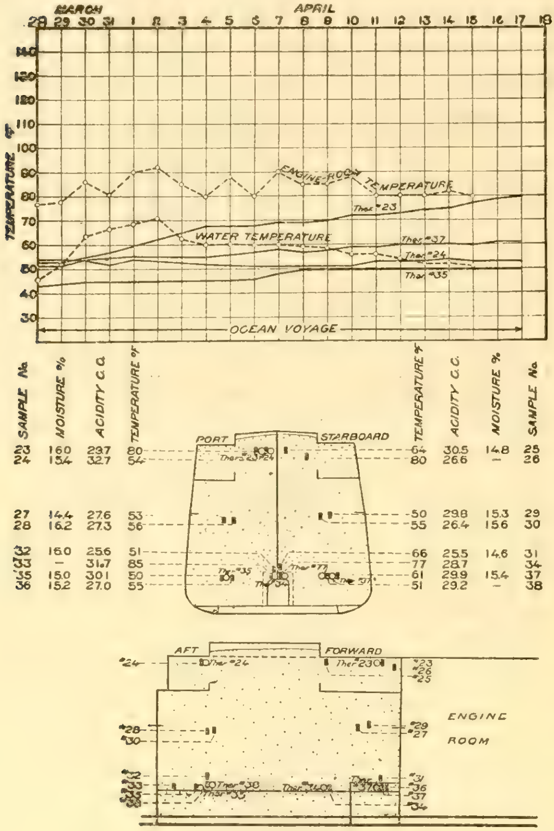


FIG. 42.—Hold 4: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 6.)

TABLE 30.—*Effect of the engine-room heat on the corn located next to the engine-room bulkhead in hold 4, cargo No. 6.*

Sample No.	Increase in temperature.	Increase in acidity.	Decrease in germination.	Decrease in sound kernels.	Decrease in weight per bushel.
	° *F.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
23[1]	27	5.3	19	28.7	2.25
24[2]	0	1.7	1	2.7	1.00

[1] Sample was located at surface against engine-room bulkhead.
[2] Sample was located same height as No. 23, but some distance from the engine-room bulkhead.

TABLE 31.—*Effect of the shaft tunnel heat on the corn stowed next to the shaft tunnel in hold 4, cargo No. 6.*

Sample No.	Increase in temperature.	Increase in acidity.	Decrease in germination.	Decrease in sound kernels.	Decrease in weight per bushel.
	° F.	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
34[1]	27	2.5	23	18.8	1.00
35 and 38*[2]	5	.1	3	8.9	1.37

[1] Sample was located on the shaft tunnel.

*Average for these two samples.

[2] Sample was located same height as No. 34, but halfway between shaft tunnel and the sides of the hold.

The effect on the corn of the heat from the engine room which penetrated through the shaft tunnel in the bottom of the hold is shown in Table 31. The corn located directly on the shaft tunnel increased 27° F. during the voyage, while the corn located the same height as the tunnel, but halfway between the tunnel and the sides of the hold, increased 7 degrees on the port side and 8 degrees on the starboard side, as is shown in figure 43. There was no heat-discolored corn in the hold at the end of the voyage, but the corn at the surface along the upper part of the engine-room bulkhead and along the top of the shaft tunnel was musty, somewhat moldy, and "packed." The corn in the hold ranged from 50° to 85° F. in temperature and 25.5 to 32.7 c. c. in acidity (4 samples tested slightly over 30 c. c. and 12 samples tested under 30 c. c. in acidity), from 7 to 52 per cent in germination, and from 57.9 to 95.6 per cent in sound kernels.

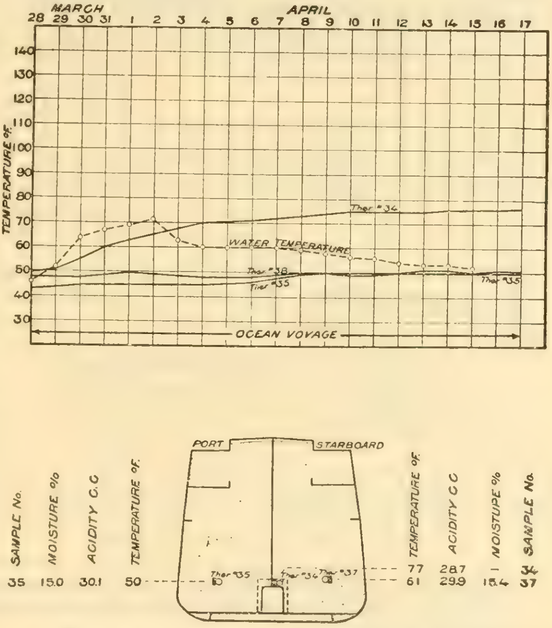


Fig. 43.—Hold 4: Showing effect of the heat from the propeller-shaft tunnel on the corn located against the tunnel. (Cargo No. 6.)

The corn in hold 5 as discharged varied from 44° to 120° F. in temperature, from 22.9 to 54.9 c. c. in acidity, and from 5 to 66 per cent in germination. A small amount of the corn a few feet under the surface in the after part of the hold was heat-damaged. Sample No. 42 taken from the heat-damaged corn had a temperature of 120° F. and tested 49 c. c. in acidity. The corn located along the upper part of the shaft tunnel was sour, moldy, and "packed." The corn near the tunnel increased more in temperature than the corn stowed the same height in the hold but located half-way between the tunnel and the sides of the hold, as is shown by comparing the records for thermometers 45, 46, and 48, and figure 45. The corn located directly on the tunnel increased more in temperature and acidity and decreased more in germination, sound kernels, and weight per bushel than the corn which was located some distance from the tunnel, also the natural corn in this hold, located on the shaft tunnel, underwent more deterioration than the dried corn located on the shaft tunnel in hold 4.

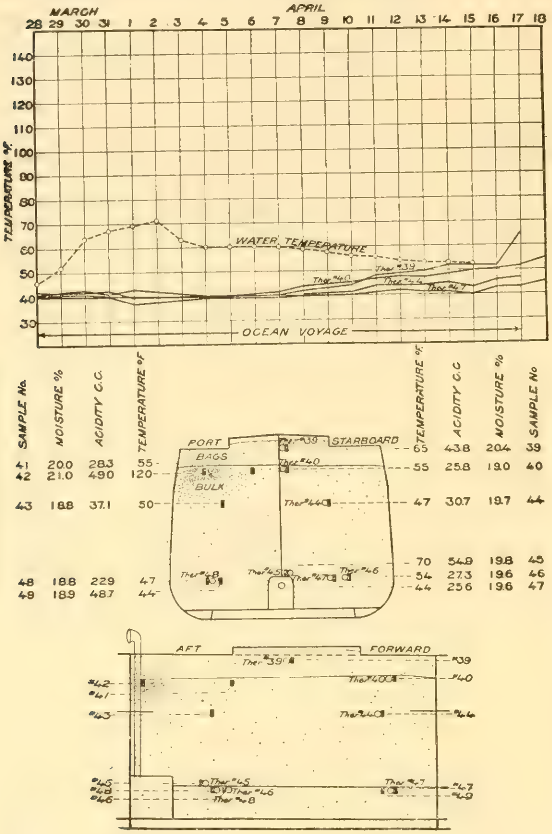


FIG. 44.—Hold 5: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 6.)

The correlation of temperature changes and changes in the condition of the corn is illustrated in figure 46.

CARGO No. 7.

Cargo No. 7 consisted of 171,428 bushels of natural corn. The corn was loaded March 23 to 27, 1911; the steamship sailed March 31 and arrived at Belfast, Ireland, April 21, where the corn was discharged from April 22 to May 9. The length of the ocean voyage was 21 days; the maximum time that any of the corn was in the vessel was 47 days, and the average time was 39 days.

STOWAGE OF THE CORN.

The steamship had six cargo holds. The corn was stowed in four holds, holds 2, 3, 5, and 6. Only hold 2 was entirely filled with corn, although the corn in hold 3 was loaded to the same height, but this hold had one more deck. Hold 5 was about two-thirds filled, and hold 6 was a little over half filled with corn. The vessel had two shaft tunnels along the bottom of holds 5 and 6. Both of these shaft tunnels were ventilated.

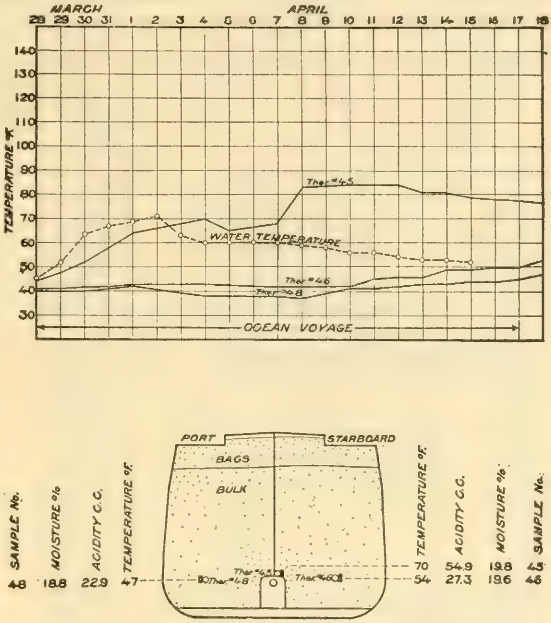


FIG. 45.—Hold 5: Showing effect of the heat from the propeller-shaft tunnel on the corn located against the tunnel. (Cargo No. 6.)

CONDITION OF THE CORN AS LOADED.

The corn in this cargo was natural corn. The condition of the corn as loaded is shown in Tables 32 and 33. The averages for the various factors of the corn as loaded were as follows: Moisture content 18.4 per cent, acidity 23.8 c. c., germination 60.2 per cent, sound kernels 95.2 per cent, and test weight per bushel 53.5 pounds. The average temperature of the corn as loaded was 62° F.

TABLE 32.—*Range in the principal factors showing quality and condition of the corn in cargo No. 7, as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° *F.*	*Per cent.*	*c. c.*	*Pre cent.*	*Per cent.*	*Pounds.*
Hold 2:						
As loaded	61.0– 67.0	16.4–18.4	26.1–29.9	46.0–64.0	90.2–96.1	52.8–54.5
As discharged	68.0–146.0	14.0–18.9	28.0–43.2	0–60.0	0–88.7	47.0–53.5
Hold 3:						
As loaded	56.0– 66.0	17.8–18.9	19.9–26.2	50.0–73.0	90.1–98.1	51.5–54.0
As discharged	65.0–141.0	16.2–20.1	27.6–47.7	0–65.0	0–91.8	47.0–53.8
Hold 5:						
As loaded	61.0– 65.0	18.5–19.0	22.1–25.9	42.0–73.0	93.9–97.7	53.5–54.5
As discharged	69.0–147.0	16.8–35.8	27.7–70.0	0–71.0	0–84.0	43.0–52.8
Hold 6:						
As loaded	57.0– 64.0	18.5–19.1	20.7–24.2	56.0–68.0	93.9–97.7	53.3–54.0
As discharged	68.0–122.0	17.1–19.1	27.5–43.4	0–61.0	0–84.8	48.0–53.8

TABLE 33.—*Condition of the corn in cargo No. 7, natural corn, as loaded, and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

[T 1, etc., represent samples in crossed-wire containers.]

Sample No.	Temperature.		Moisture content.		Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 2:	° F.	° F.	P. ct.	P. ct.	c. c.	c. c.	P. ct.	P. ct.	P. ct.	P. ct.	Lbs.	Lbs.
T 1....	67	146	17.8	18.0	26.1	42.8	47	0	95.4	0	53.25	47.00
T 2 ...	63	126	18.4	16.7	26.9	38.2	58	1	95.5	1.0	54.00	50.50
36.....	......	......	......	14.0	......	33.8	......	6	......	39.5	......	52.50
T 3 ...	63	76	18.4	17.9	29.9	43.2	46	3	96.1	21.1	54.50	51.50
37.....	......	116	......	18.5	......	28.4	......	28	......	65.5	......	50.00
38.....	......	112	......	18.9	......	33.7	......	3	......	9.1	......	49.50
39.....	......	82	......	17.7	......	28.0	......	36	......	70.9	......	51.50
40.....	......	70	......	17.8	......	29.0	......	47	......	77.2	......	53.00
T 4....	65	69	16.4	17.2	27.1	32.0	58	42	90.5	88.7	53.50	52.25
T 5....	66	82	17.2	16.8	27.7	31.0	64	60	90.2	87.4	52.75	52.50
41.....	......	68	......	17.6	......	29.0	......	37	......	85.8	......	53.00
T 6....	61	70	17.7	17.2	28.5	29.3	60	51	90.8	77.1	53.00	52.75
T 7....	64	68	18.3	18.3	26.7	32.6	60	60	92.2	84.5	53.75	53.50
42.....	......	......	18.3	......	26.3	......	53	......	93.8	......	53.50	......
43.....	......	......	17.7	......	28.2	......	61	......	95.4	......	53.50	......
44.....	......	......	17.3	......	27.1	......	61	......	92.6	......	53.00	......
Hold 3:												
T 8....	66	141	18.5	18.3	22.2	43.6	60	0	96.0	0	53.25	47.00
T 9....	66	140	18.3	17.5	23.8	47.7	62	0	96.1	0	53.25	47.50
45.....	......	118	......	20.1	......	41.7	......	14	......	29.7	......	47.00
T 10...	66	118	18.2	16.2	......	34.0	......	34	95.4	18.4	54.00	52.00
46.....	......	104	......	17.3	......	28.0	......	51	......	62.1	......	51.50
47.....	......	78	......	17.9	22.4	29.6	65	3	......	80.6	......	53.00
48.....	......	67	......	18.7	......	31.7	......	35	......	55.7	......	52.50
49.....	......	70	......	18.1	......	31.0	......	44	......	83.9	......	52.00
T 11...	64	73	18.6	18.2	20.5	31.7	53	65	98.1	91.8	54.00	52.75
T 12...	64	72	18.1	18.3	25.0	31.0	62	56	95.5	80.6	53.50	52.25
T 13...	64	69	18.1	17.7	21.2	33.8	65	59	97.6	86.5	53.50	53.75
T 14...	64	70	18.9	18.6	22.0	27.6	60	61	95.6	82.7	53.00	52.75
T 15...	63	72	18.1	17.7	19.9	29.2	63	44	96.8	74.8	53.25	52.00
T 16...	62	65	18.8	18.3	20.8	31.0	65	65	95.8	74.8	53.25	52.00
T 17...	62	68	18.6	18.0	21.8	31.2	67	57	93.2	84.6	53.00	52.50
T 18...	61	69	18.7	18.4	21.8	32.0	55	58	90.1	87.5	51.50	51.25
T 19...	58	69	18.8	18.8	26.2	30.8	62	59	94.0	88.7	53.50	53.50
T 20...	59	70	18.3	17.7	21.2	30.0	60	64	95.3	78.3	53.75	53.00
T 21...	56	72	18.1	18.1	22.4	27.6	61	64	96.7	83.6	54.00	52.50
50.....	......	......	18.2	......	20.0	......	73	......	95.0	......	53.50	......
51.....	......	......	18.0	......	22.4	......	59	......	96.0	......	53.00	......
52.....	......	......	17.8	......	23.2	......	61	......	95.6	......	53.75	......
Hold 5:												
T 22...	63	147	18.8	16.8	24.2	47.4	59	0	95.9	0	53.50	47.50
53.....	......	135	......	18.8	......	36.7	......	0	......	2.9	......	49.75
54.....	......	......	......	35.8	......	70.0	......	0	......	0	......	43.00
55.....	......	118	......	19.2	......	27.7	......	1	......	13.3	......	50.00
56.....	......	71	......	18.1	......	29.3	......	62	......	82.5	......	52.75
T 23...	65	74	18.5	18.5	23.2	32.4	42	56	97.6	76.7	53.75	52.50
T 24...	64	77	18.6	18.4	22.9	34.7	73	67	96.1	76.1	53.75	51.75
57.....	......	125	......	......	......	51.8	......	6	......	5.5	......	......
58.....	......	83	......	18.7	......	29.6	......	1	......	72.4	......	50.00
T 25...	65	90	18.6	18.9	25.9	33.3	63	3	96.4	66.9	54.00	51.00
59.....	......	72	......	18.4	......	30.5	......	37	......	76.4	......	51.00
T 26...	64	79	18.6	18.4	22.1	31.3	68	70	95.8	66.9	54.50	52.00
60.....	......	69	......	......	......	28.7	......	60	......	62.4	......	......
T 27...	64	69	18.5	17.4	25.5	30.3	57	62	96.7	84.4	53.75	52.50
T 28...	61	73	18.6	18.6	23.2	30.2	67	71	95.7	69.8	53.50	52.50
61.....	......	......	18.8	......	24.4	......	62	......	97.7	......	54.00	......
62.....	......	......	19.0	......	23.8	......	62	......	95.4	......	54.00	......
63.....	......	......	18.8	......	25.4	......	67	......	93.9	......	54.00	......
Hold 6:												
64.....	......	72	......	17.1	......	38.1	......	4	......	9.8	......	48.00
T 29...	63	122	18.7	18.3	20.9	43.4	57	0	96.3	0	53.50	49.50
65.....	......	100	......	18.9	......	39.8	......	0	......	33.8	......	51.25
66.....	......	80	......	17.1	......	31.8	......	29	......	76.9	......	51.50
67.....	......	87	......	19.1	......	32.8	......	0	......	71.4	......	50.00
T 30...	61	87	18.7	18.1	20.7	30.8	56	23	95.4	69.8	53.50	51.25
T 31...	63	86	18.8	17.8	23.6	29.9	62	33	95.3	83.1	54.00	52.25
T 32...	64	75	18.9	18.2	20.7	30.1	57	55	93.9	74.3	53.25	51.50
T 33...	63	68	18.5	18.3	23.7	28.4	56	56	97.7	82.9	53.50	53.75
T 34...	......	......	18.5	18.3	24.2	33.0	62	61	96.3	84.8	54.00	53.25
T 35...	57	69	19.1	18.4	22.3	27.5	68	58	97.1	78.5	53.50	53.00
68.....	......	......	18.6	......	22.9	......	59	......	94.7	......	54.00	......

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

During the voyage the temperature of the corn in the various positions of stowage was recorded each day that the weather permitted. The location of the various thermometers and the changes in temperature at those positions are shown in figures 48 to 53, inclusive. The maximum temperatures found in the corn as discharged were 146° F. in hold 2, 141° F. in hold 3, 147° F. in hold 5, and 122° F. in hold 6. These were higher than the maximum temperatures at the time of loading by 79° F., 75° F., 82° F., and 58° F., respectively. During the time that the corn was in the vessel a large proportion of it became hot, discolored, moldy, and badly damaged. The corn changed the most in condition and became badly damaged in the upper part of the holds. The temperature and degree of deterioration, in a general way, decreased from the surface of the corn toward the bottom of the holds. It will be seen in the accompanying charts that the temperature of the corn reached 100° F. in the following number of days after sailing. Three days in hold 2, 4½ days in hold 3, 8 days in hold 5, 16 days in hold 6. As has already been stated, the average length of time that the corn remained in the vessel was 39 days.

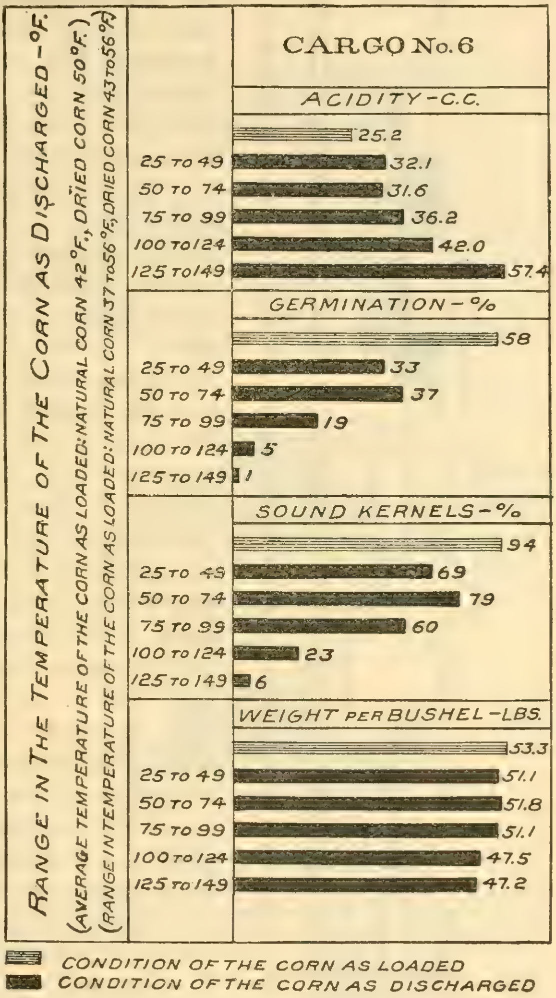


FIG. 46.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 6.)

Hold 2 was entirely filled with corn, the upper part of which became badly heat damaged while it was in the vessel. The corn in this hold as discharged ranged from 68 to 146 degrees in temperature, 14 to 18.9 per cent in moisture, 28 to 43 c. c. in acidity, 0 to 60 per cent in germination, 0 to 88.7 per cent in sound kernels, and 47 to 53.5 pounds in test weight per bushel. As is shown in Table 33, sample 1, taken from near the surface, had a temperature when discharged of 146° F., tested 42.8 c. c. in acidity, had no sound kernels, and none of the corn would germinate. As will be seen by the temperature record for thermomter 1, in figure 48, this thermometer was located near the surface. The corn in this position of stowage increased in temperature very rapidly from the time it was loaded, on March 27, until it was over 140° F., on April 12, after which the increase became more gradual. The corn surrounding this thermometer was very badly damaged on arrival in Europe. Sample 2, which was taken from the corn about one-third of the distance down in the hold, had a temperature of 126° F., tested 38.2 c. c. in acidity, germinated 1 per cent, and had 1 per cent of sound kernels. The temperature of the corn surrounding sample 2 gradually increased from the time that the corn was loaded until it was discharged, as is shown by the temperature record for thermometer 2. Sample 4, taken two-thirds of the distance down in the corn, and sample 7, taken from the bottom of the hold, had temperatures of 69° and 68° F., and tested 32 and 32.6 c. c. in acidity, 42 and 60 per cent in germination, and 88.7 and 84.5 per cent in sound kernels. The temperature of the corn two-thirds of the distance down in the hold remained practically stationary during the voyage, as will be seen by the records for thermometer 4, while the temperature of

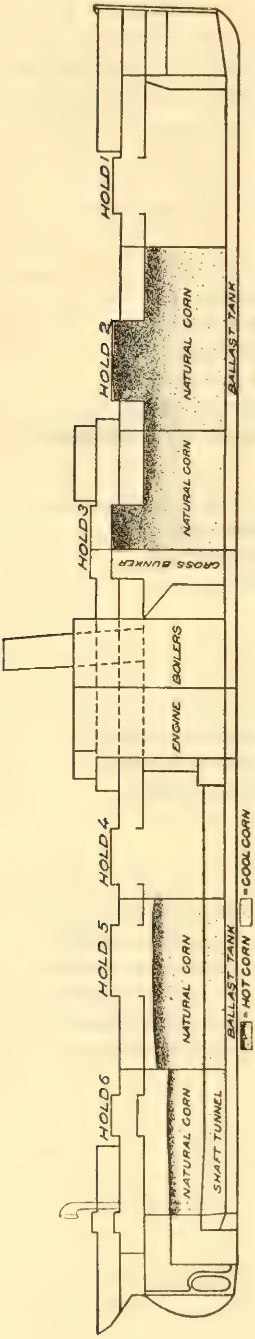
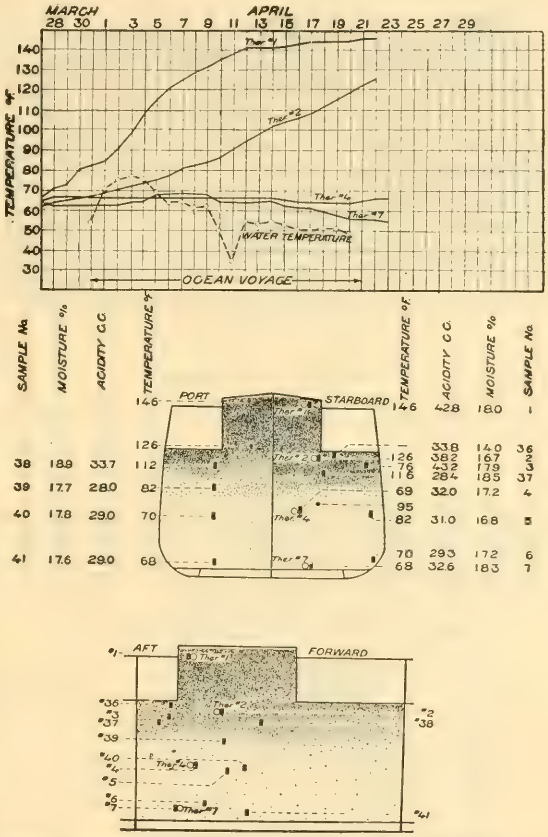


FIG. 47.—Diagram showing arrangement of the steamship and stowage of the corn in holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 7.)

the corn at the bottom fluctuated somewhat, being influenced to some extent by the temperature of the sea water.



SAMPLE No.	MOISTURE %	ACIDITY C.C.	TEMPERATURE °F.
			146
			126
38	18.9	33.7	112
39	17.7	28.0	82
40	17.8	29.0	70
41	17.6	29.0	68

TEMPERATURE °F.	ACIDITY C.C.	MOISTURE %	SAMPLE No.
146	42.8	18.0	1
—	33.8	14.0	36
126	38.2	16.7	2
76	43.2	17.9	3
116	28.4	18.5	37
69	32.0	17.2	4
95			
82	31.0	16.8	5
70	29.3	17.2	6
68	32.6	18.3	7

Fig. 48.—Hold 2: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Belfast. Heavy shading represents heat-damaged corn. (Cargo No. 7.)

Hold 3 was filled with corn to the second deck. The corn as discharged was badly heat damaged in the upper part of the hold and ranged from 65° to 141° F. in temperature, 27.6 to 47.7 c. c. in acidity, 0 to 65 per cent in germination, 0 to 91.8 per cent in sound kernels, and 47 to 53.8 in test weight per bushel. The corn in this hold at time of loading had a temperature ranging from 56° to 66° F., which temperature increased very rapidly at the surface during the early part of the voyage and was over 120° F. in a week after the vessel sailed; it continued to increase until it reached 141° F. by the time the corn was discharged. This is shown in the temperature record for thermometer 8, figure 49. As will be seen in Table 33, sample No. 8, which was taken from near the surface of the corn, tested 43.6 c. c. in acidity and none of the kernels would germinate. The corn at this position was very moldy, sour, and badly heat damaged. There was not much change in the temperature of the corn located one-third of the distance down in the hold in the first 10 or 12 days of the voyage, but from that time on it increased more rapidly until on April 24 it was 118° F., as is shown by the record for thermometer 10. The corn surrounding this thermometer, as discharged, tested 34 c. c. in acidity and 34 per cent in germination. The temperature of the corn located two-thirds of the distance down in the hold increased only 9° F. during the time it was in the vessel, as is shown by the temperature record for thermometer 11. Sample No. 11, taken from the corn surrounding thermometer 11, had a temperature of 73° F. and tested 31.7 c. c. in acidity, 65 per cent in germination, and 91.8 per cent in sound kernels. The temperature of the corn in the bottom of the hold varied somewhat with the sea-water temperature, as illustrated by the record for thermometer 19. Sample No. 19, taken from the corn at the bottom of the hold, had a temperature when discharged of 69° F., tested 30.8 c. c. in acidity, 59 per cent in germination, and 88.7 per cent in sound kernels.

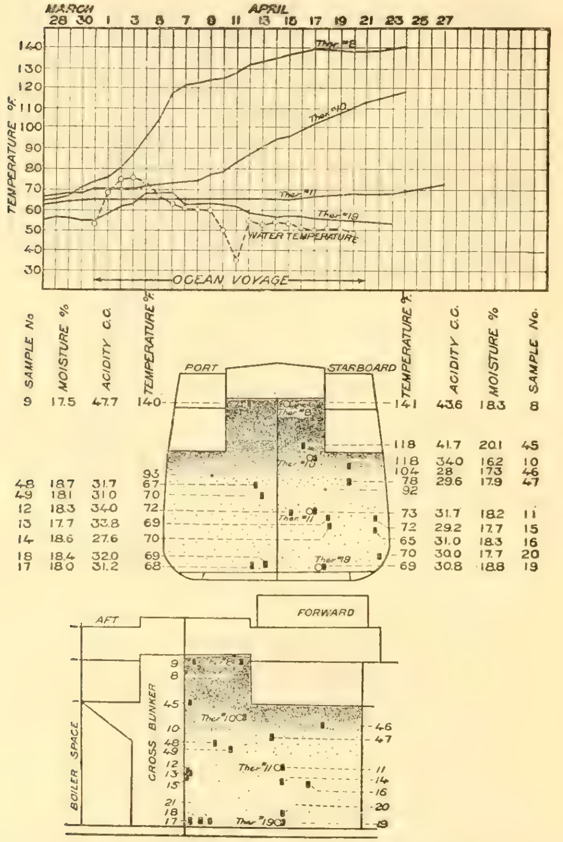


FIG. 49.—Hold 3: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Belfast. Heavy shading represents heat-damaged corn. (Cargo No. 7.)

Hold 5 was two-thirds filled with corn, the top part of which became badly heat damaged during the voyage. The corn in this hold, as discharged, ranged from 69° to 147° F. in temperature, 27.7 to 70 c. c. in acidity, 0 to 71 per cent in germination, 0 to 84 per cent in sound kernels, and 43 to 52.8 pounds in test weight per bushel. As will be seen by the temperature record for thermometer 22 in figure 12, the corn near the surface increased from 63° F. on March 24 to 100° F. on April 8 and to 147° F. on April 21. As indicated in Table 33, sample No. 22, which represents the corn surrounding thermometer No. 22, contained no sound kernels or any kernels that would germinate, and tested 47.4 c. c. in acidity and 47.5 pounds in weight per bushel. The corn located halfway down in the hold and at the bottom changed very little in temperature except near the outside walls and along the top of the shaft tunnel. Sample No. 24, taken from near the shifting boards halfway down in the corn, increased from 64 to 77° F. in temperature and when discharged tested 34.7 c. c. in acidity, 67 per cent in germination, 76.1 per cent in sound kernels, and 51.75 pounds in weight per bushel. Sample No. 57, taken from near the side of the hold, a little over halfway down in the corn on the port side, had a temperature of 125° F. and tested 51.8 c. c. in acidity, 6 per cent in germination, and 5.5 per cent in sound kernels. The corn along the top of the shaft tunnel varied in temperature during the voyage, while the temperature of the corn the same height in the hold located halfway from the tunnel and the side of the boat, remained nearly the same throughout the voyage, as is shown by comparing the temperature records for thermometers 25 and 26.

Table 34 shows that the corn surrounding thermometer 25, which was located on the shaft tunnel, tested higher by 2 c. c. in acidity and lower by 67 per cent in germination than the corn surrounding thermometer 26, which was located at tunnel height but halfway between the tunnel and the side of the hold. Four samples taken from hold 5 tested under 30 c. c. and nine samples tested over 30 c. c. in acidity.

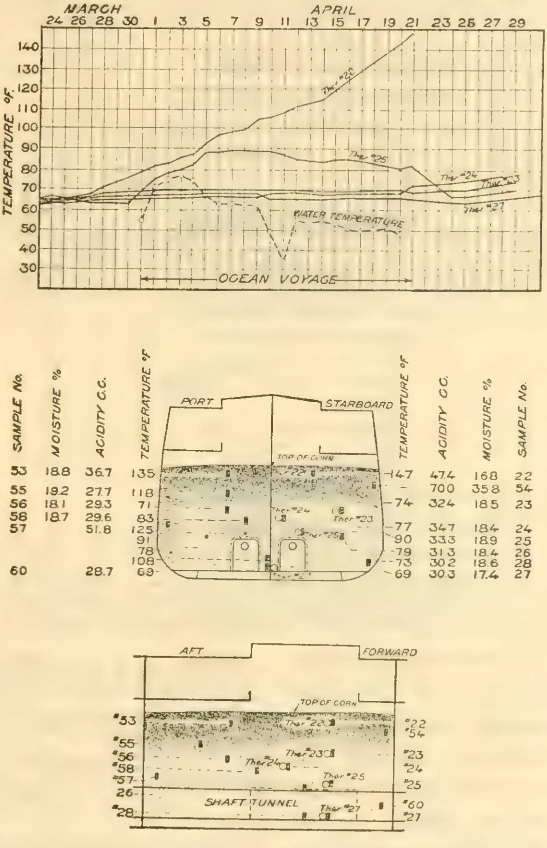


FIG. 50.—Hold 5: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Belfast. Heavy shading represents heat-damaged corn. (Cargo No. 7.)

TABLE 34.—*Effect of the shaft-tunnel heat on the corn stowed next to the shaft tunnel in hold 5.*

Sample No.	Location of samples.	Temperature.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
		° *F.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
25	On shaft tunnel	90	33.3	3	66.9	51.0
26	Tunnel height halfway out	79	31.3	70	66.9	52.0

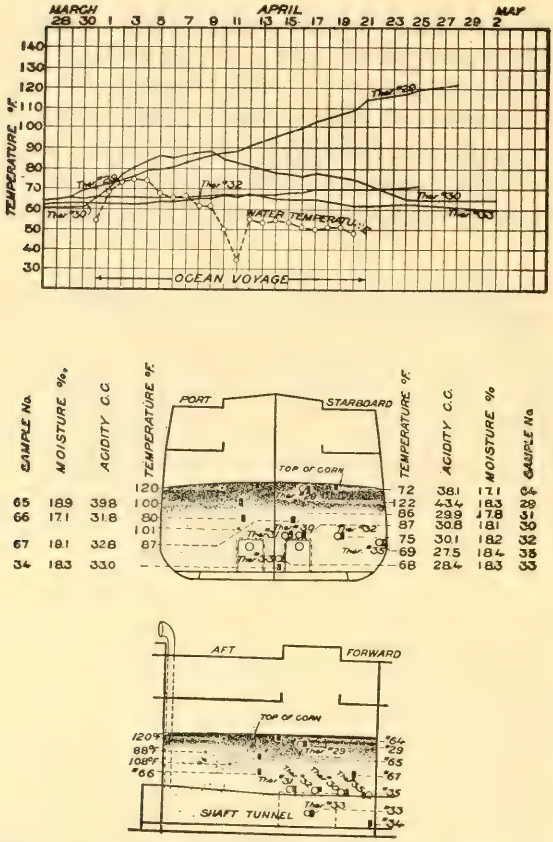


FIG. 51.—Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Belfast. Heavy shading represents heat-damaged corn. (Cargo No. 7.)

Hold 6 was a little more than half filled with corn. The upper part of the corn became badly heat damaged. The corn in this hold as discharged ranged from 68° to 122° F. in temperature, 27.5 to 43.4 c. c. in acidity, 0 to 61 per cent in germination, 0 to 84.8 per cent in sound kernels, and 48 to 53.8 pounds in test weight per bushel. The corn at the surface, where the heat could escape, had a temperature of 72° F. when discharged, as is shown by sample No. 64 in figure 51. The corn just under the surface gradually increased from 63° to 122° F. during the voyage, as is illustrated by the temperature record for thermometer 29. As is shown in Table 33, sample No. 29, which represents the corn surrounding thermometer No. 29, tested 43.4 c. c. in acidity, and 49.5 pounds in weight per bushel, and contained no sound kernels or any kernels that would

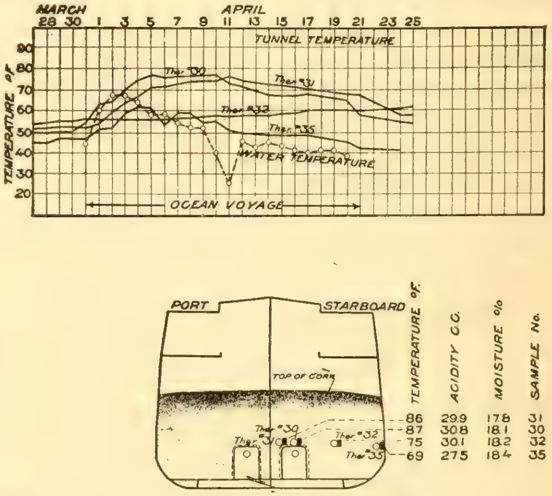


FIG. 52.—Hold 6, showing effect of the heat from the propeller-shaft tunnels on the corn located against the tunnels. (Cargo No. 7.)

germinate. The corn located about 6 feet from the bottom and halfway between the shaft tunnel and the side of the hold increased 11° F. in temperature and tested 30.1 c. c. in acidity, 55 per cent in germination, 74.3 per cent in sound kernels, and 51.5 pounds in weight per bushel, as is shown by sample No. 32, while the corn between the tunnels and near the bottom of the hold increased but 5° F. in temperature and tested 28.4 c. c. in acidity, 56 per cent in germination, 82.9 per cent in sound kernels, and 53.75 pounds in weight per bushel, as is shown by sample No. 33.

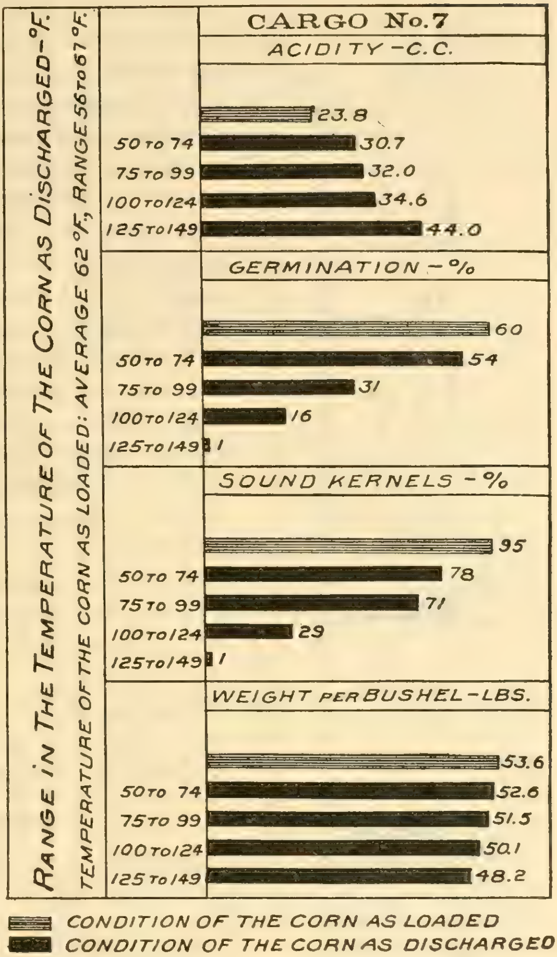


FIG. 53.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 7.)

TABLE 35.—*Effect of the shaft-tunnel heat on the corn stowed next to the shaft tunnel in hold 6.*

Sample No.	Location of samples.	Temperature.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
		° F.	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
30	On unprotected part of shaft tunnel	87	30.8	23	69.8	51.2
31	On plank-protected part of shaft tunnel	86	29.9	33	83.1	52.2
30 and 31	On shaft tunnel[1]	86	30.3	28	71.4	51.7
32	Tunnel height, halfway out	75	30.1	55	74.3	51.5

[1] Average for samples Nos. 30 and 31.

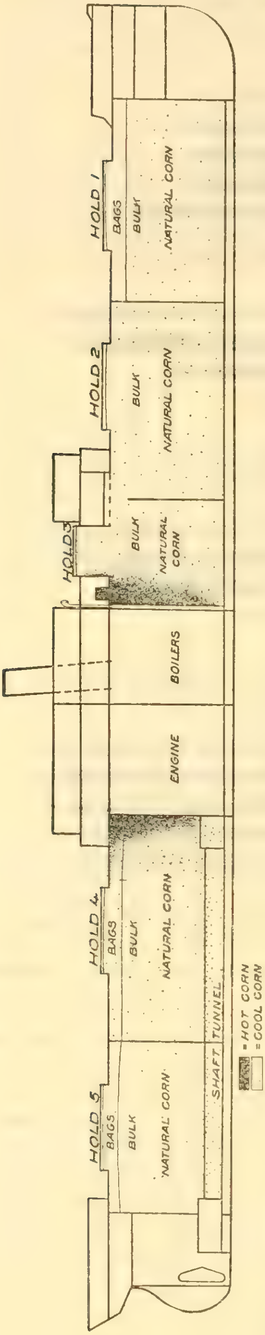


FIG. 54.—Diagram showing the arrangement of the stowage of the corn in holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 8.)

As will be seen in figure 52 and Table 35, the corn which was located on the unprotected part of the shaft tunnel was influenced more by the tunnel temperature and tested poorer when discharged than the corn which was located on the plank-protected part of the tunnel. They also show that the corn in either of the two positions on the shaft tunnel varied considerably more in temperature and tested poorer than the corn located at tunnel height but halfway between the tunnel and the side of the hold. The temperature of the corn at tunnel height near the side of the hold varied with the sea temperature as is illustrated by the temperature record for thermometer 35.

Three samples taken from hold 6 when the corn was being discharged tested under 30 c. c. and eight samples tested over 30 c. c. in acidity.

The correlation of temperature changes and changes in the condition of the corn is illustrated in figure 53.

CARGO No. 8.

Cargo No. 8 consisted of 258,092 bushels of natural corn. The corn was loaded from February 27 to March 1, 1912. The steamship sailed March 1 and arrived at Rotterdam, Holland, on March 20, where the corn was discharged from March 20 to March 22. The length of the ocean voyage was 19 days; the maximum time that any of the corn was in the vessel was 23 days, and the average time was 21 days.

STOWAGE OF THE CORN.

The steamship had five cargo holds. As is shown in figure 54, this shipment was a full cargo, each hold being entirely filled with corn.

CONDITION OF THE CORN AS LOADED.

The corn in this cargo was natural corn, and its condition as loaded is shown in Tables 36 and 37. The averages for the various factors of the corn as loaded were as follows: Moisture content 20.1 per cent, acidity 17.6 c. c., germination 49 per cent, sound kernels 88 per cent, and test weight per bushel 52.7 pounds. The average temperature of the corn as loaded was 29° F.

TABLE 36.—*Range in the principal factors showing quality and condition of the corn in cargo No. 8, as loaded and as discharged, by holds.*

Hold.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° *F.*	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 1:						
As loaded	25. 0– 32. 0	19. 9–20. 3	17. 6–18. 5	45. 0–66. 0	85. 5–94. 1	52. 5 –54. 0
As discharged	25. 0– 46. 0	....	17. 8–21. 2	24. 0–53. 0	84. 9–93. 0	51. 75–54. 0
Hold 2:						
As loaded	27. 0– 32. 0	19. 9–20. 4	16. 8–18. 6	48. 0–57. 0	87. 0–88. 9	52. 0 –53. 5
As discharged	29. 0– 52. 0	....	18. 0–28. 0	10. 4–40. 0	83. 6–91. 1	51. 2 –53. 5
Hold 3:						
As loaded	26. 0– 33. 0	19. 8–20. 5	17. 6–20. 2	36. 0–58. 0	86. 7–91. 4	51. 5 –53. 5
As discharged	28. 0–132. 0	....	18. 2–38. 2	0–39. 0	2. 0–91. 1	46. 5 –53. 5
Hold 4:						
As loaded	26. 0– 32. 0	19. 5–20. 3	15. 6–19. 2	30. 0–69. 0	85. 5–94. 1	51. 5 –53. 5
As discharged	29. 0–145. 0	....	16. 6–50. 4	0–45. 0	0–95. 4	46. 0 –53. 25
Hold 5:						
As loaded	24. 0– 33. 0	19. 5–20. 6	16. 6–18. 0	37. 0–65. 0	86. 9–91. 6	52. 5 –53. 2
As discharged	27. 0– 84. 0	....	18. 0–32. 0	4. 0–52. 0	58. 1–91. 0	47. 0 –53. 5

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

The temperatures of the corn in the various positions of stowage were recorded during the voyage each day that the weather permitted. The location of the various thermometers and the changes in the temperature at those positions are shown in figures 55 to 62, inclusive. It will be noted that at the time of loading the average temperature of the corn was very low (30° F.) and that the moisture content was dangerously high (20.1 per cent). However, the acidity was very low (17.6 c. c.), showing that the corn had previously undergone very little deterioration. At the time of discharge it was found that the corn in holds 3 and 4 was damaged along the boiler-room and engine-room bulkheads and there was also a slight amount of damage along the shaft tunnel in the bottom of holds 4 and 5. The maximum temperatures found in the corn as discharged were 46° F. in hold 1, 52° F. in hold 2, 132° F. in hold 3, 145° F. in hold 4, and 84° F. in hold 5. These were higher than the maximum temperatures at the time of loading by 14° F. in hold 1, 20° F. in hold 2, 109° F. in hold 3, 123° F. in hold 4, and 51° F. in hold 5.

There were no facilities for making moisture tests of the samples secured at the port of discharge, and consequently the moisture tests at the time of loading only are given in this report.

TABLE 37.—*Condition of the corn in cargo No. 8 as loaded and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

[T 1, etc., represent samples in crossed-wire containers.]

Sample No.	Temperature.		Moisture content.	Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.	As loaded.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1:	°*F.*	°*F.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
T 1	30	42	19.9	17.6	21.2	45	27	93.3	90.0	53.00	52.75
2	......	43	......	......	20.6	......	24	......	87.7	......	51.75
T 3	32	32	20.3	18.8	20.0	47	27	85.5	84.9	52.50	52.00
4	......	......	......	......	17.8	......	36	......	90.4	......	54.00
T 5	25	25	20.1	17.8	17.8	66	53	93.8	91.6	54.00	53.75
6	......	33	......	......	21.2	......	27	......	93.0	......	52.75
T 7	31	46	20.2	17.8	19.6	60	30	94.1	86.0	52.50	51.75
Hold 2:											
T 8	32	52	20.1	16.8	18.2	48	34	88.6	88.5	53.50	53.00
T 9	31	49	20.2	17.8	25.4	57	15	88.9	85.8	52.00	52.00
10	......	......	......	......	28.0	......	10	......	84.0	......	53.00
11	......	......	......	......	19.2	......	34	......	91.1	......	53.00
T 12	29	30	19.9	18.2	18.2	52	40	88.2	88.0	53.50	52.50
T 13	29	29	20.1	18.6	18.6	55	32	87.0	86.9	52.00	52.00
14	......	38	......	......	18.0	......	38	......	86.5	......	52.25
T 15	27	39	20.4	17.2	18.0	53	28	87.6	83.6	52.00	51.25
Hold 3:											
T 16	27	55	20.1	17.8	21.4	56	29	87.0	82.5	53.00	52.00
T 17	30	68	20.1	19.2	26.2	43	7	89.6	88.4	52.50	50.00
T 18	30	59	20.2	18.4	21.4	49	21	91.4	91.1	53.00	51.00
19	......	78	......	......	38.2	......	4	......	61.2	......	48.00
T 20	31	132	20.1	18.0	27.8	46	0	87.8	2.0	53.00	46.50
T 21	31	32	20.5	18.2	20.4	36	6	91.1	89.6	53.00	52.50
T 22	33	112	20.2	20.2	22.6	58	26	87.9	......	52.00	51.75
T 23	26	28	19.8	17.6	18.2	56	39	90.4	89.4	53.50	53.50
T 24	33	53	20.4	17.8	18.6	53	32	90.0	84.0	51.50	51.50
25	29	......	20.3	18.8	......	47	......	86.7	......	51.50	......
Hold 4:											
T 26	28	33	20.3	18.4	20.0	48	45	91.9	91.9	53.00	52.75
T 27	30	35	19.9	19.2	20.0	36	31	94.1	94.0	53.00	52.50
28	32	......	19.8	17.6	24.6	31	20	90.6	79.3	52.50	51.50
29	32	......	19.9	17.6	......	39	......	87.2	......	52.50	......
T 30	32	145	20.2	17.6	43.8	37	0	87.5	0	53.50	46.00
31	......	140	......	......	50.4	......	1	......	0	......	46.50
32	31	32	20.1	18.6	19.2	43	23	89.5	88.7	53.00	52.75
33	......	45	......	......	42.2	......	14	......	......	......	49.50
34	......	40	......	......	23.6	......	25	......	95.3	......	51.75
35	......	138	......	......	32.0	......	0	......	0	......	46.25
T 36	31	115	19.7	17.2	40.2	30	3	90.0	15.1	53.00	47.50
T 37	32	115	20.2	18.8	40.4	48	0	86.4	0	52.50	46.00
T 38	29	30	20.0	18.0	18.8	47	25	85.9	85.7	53.50	53.25
39	......	116	......	......	39.6	......	2	......	15.4	......	46.50
40	......	38	......	......	19.6	......	14	......	95.4	......	52.25
T 41	32	56	20.0	15.6	16.8	69	31	87.3	82.2	52.50	51.25
T 42	31	48	20.3	17.6	20.2	52	25	87.9	85.4	52.00	52.00
T 43	26	67	19.5	16.0	23.0	67	10	86.1	84.8	51.50	50.00
44	......	98	......	......	37.4	......	5	......	30.0	......	47.75
T 45	27	29	20.2	16.6	16.6	59	34	89.6	89.0	53.00	53.00
T 46	27	31	20.2	17.2	18.8	57	35	90.4	90.0	52.50	52.25
47	......	38	......	......	20.4	......	26	......	93.1	......	52.50
T 48	28	43	20.1	16.8	17.6	30	30	85.5	85.4	53.00	52.50
Hold 5:											
49	30	......	20.0	17.0	......	37	......	88.2	......	52.50	......
50	......	44	......	......	23.4	......	23	......	91.0	......	52.25
T 51	32	32	20.5	17.2	32.0	38	38	89.2	85.9	52.50	51.75
52	......	38	......	......	20.8	......	28	......	90.9	......	53.25
T 53	28	28	20.4	18.0	18.6	65	46	87.1	84.1	53.00	53.00
T 54	29	84	19.8	16.8	29.4	50	4	86.6	58.1	53.25	48.75
55	......	82	......	......	28.2	......	8	......	68.0	......	47.00
56	......	38	......	......	21.4	......	28	......	89.9	......	53.50
T 57	28	29	20.3	16.6	18.8	41	21	91.6	90.5	52.50	52.00
T 58	24	27	19.5	17.2	18.0	61	52	87.4	87.0	53.25	53.25
T 59	28	43	20.1	17.0	19.4	49	26	89.2	87.6	53.00	53.00
T 60	33	43	20.6	16.6	20.6	47	21	88.1	88.0	52.50	52.50

The corn in holds 1 and 2 changed but little during the voyage and was discharged in Europe in good condition.

In hold 3 that part of the corn that was located next to the boiler-room bulkhead in the after part of the hold was hot and badly damaged at the time of discharge. In the damaged corn, as is shown in Table 38, the greatest heat and the most severe damage was found along the upper part of this bulkhead. The corn located along the lower part of this bulkhead was not hot but was slightly sour. The corn located in the forward part of the hold was discharged in a sound condition. The temperature records during the voyage for the corn located next to the upper, middle, and bottom portions of the boiler-room bulkhead, compared to the temperature records of the corn located at the same heights but near the center of the hold, are shown in figure 57. As will be seen from the temperature records in figure 57, the temperature of the corn located against the upper, middle, and bottom parts of the bulkhead was very noticeably affected by the heat from the boilers. Table 38 shows that the corn located against the upper part of the boiler-room bulkhead, at the time of discharge, had a temperature of 132° F., as against a temperature of 32° F. for the corn located the same height in the hold but 15 feet distant from this bulkhead, and that the corn located against the bottom of the boiler-room bulkhead at the time of discharge, had a temperature of 53° F., as against a temperature of 39° F. for the corn

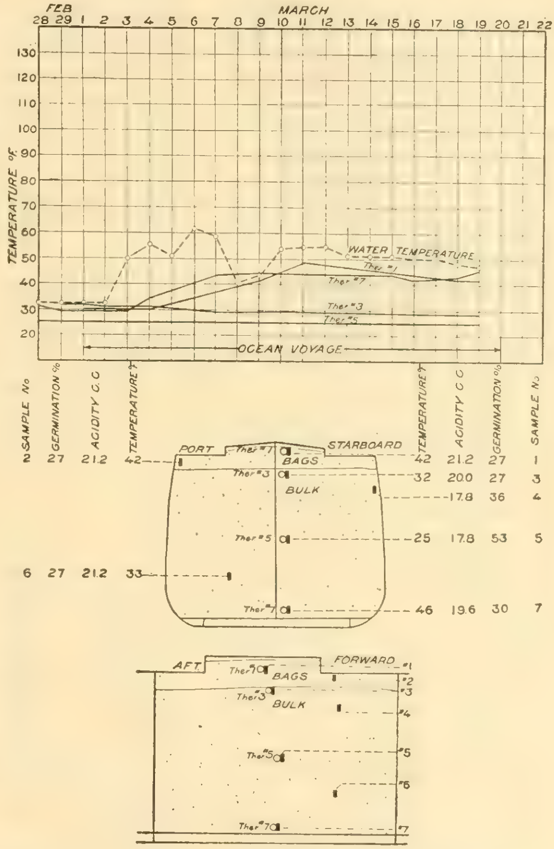


FIG. 55.—Hold 1: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 8.)

TABLE 38.—*Showing effect of the boiler heat on the corn in hold 3, cargo No. 8.*

Location of corn.		Sample No.	Temperature.[1]			Moisture content as loaded.	Weight per bushel.			Germination.			Acidity.			Sound kernels.		
Height in hold.	Distance from boiler-room bulkhead.[2]		As loaded.	As discharged.	+ or −		As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −
			° F.	° F.	° F.	Per ct.	Lbs.	Lbs.	Lbs.	Per ct.	Per ct.	Per ct.	c. c.	c. c.	c. c.	Per ct.	Per ct.	Per ct.
Top	On BRBH	20	31	132	+ 101	20.1	53.00	46.50	−6.50	46	0	− 46	18.0	27.8	+9.8	87.8	2.0	−85.8
Top	15 feet, BRBH.	21	31	32	+ 1	20.5	53.00	52.50	− .50	36	6	− 30	18.2	20.4	+2.2	91.0	89.6	− 1.5
Halfway down	On BRBH	22	33	112	+ 79	20.2	52.00	51.75	− .25	58	26	− 32	20.2	22.6	+2.4	87.9	82.0	− 5.9
Halfway down	15 feet, BRBH.	23	26	28	+ 2	19.8	53.50	53.50	0	56	39	− 17	17.6	18.2	+ .6	90.4	89.4	− 1.0
Bottom	On BRBH	24	33	53	+ 20	20.4	51.50	51.50	0	53	32	− 21	17.8	18.6	+ .8	90.0	84.0	− 6.0
Bottom	30 feet, BRBH.	[3] 25	29	39	+ 10	20.3	51.50	51.50	0	47	28	− 19	17.8	18.0	+ .2	86.7	83.6	− 3.1

CHANGE DUE TO BOILER HEAT.

[In excess of change in corn located same height but from 15 to 30 feet distant from the boiler-room bulkhead.]

Top	On BRBH				+ 100				−6.00			− 16			+ 7.6			−84.3
Halfway down	On BRBH				+ 77				− .25			− 15			+ 1.8			− 4.9
Bottom	On BRBH				+ 10				− .00			− 2			+ .6			− 2.9

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[1] The plus (+) sign means increase, and the minus (−) sign means a decrease.

[2] BRBH=boiler-room bulkhead.

[3] No. 25 was lost; Rotterdam data represents sample No. 15 in hold 2, same relative location.

at the bottom of the hold but located 30 feet distant from this bulkhead. This was a higher increase in temperature by 100°, 77°, and 10° F., for the corn located against the upper, middle, and bottom parts of the boiler-room bulkhead, respectively, than the increase in temperature for the corn located at a corresponding depth in the hold but from 15 to 30 feet distant from this bulkhead, and clearly shows the effects of the boiler heat on corn having a high moisture content when stowed in this position in the vessel.

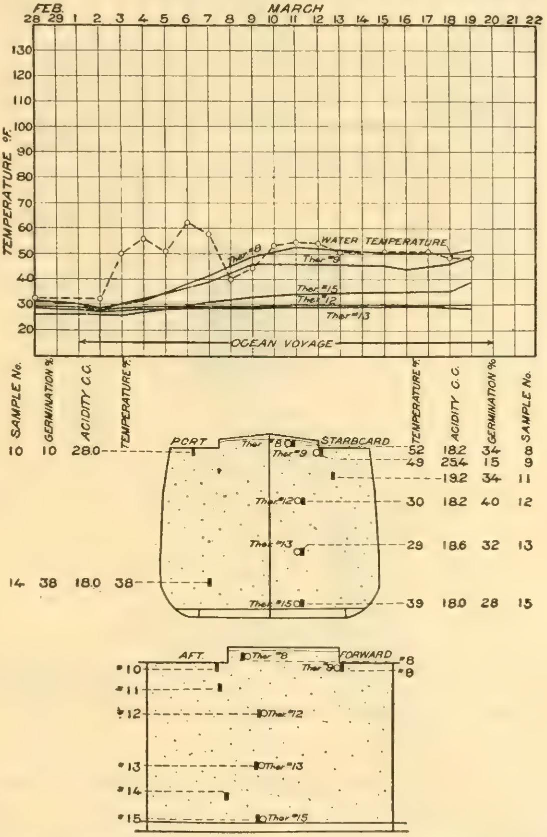

FIG. 56.—Hold 2: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 8.)

Hold 4 was located just aft of the engine room. The propeller-shaft tunnel was located along the bottom of the hold, and this tunnel also extended along the bottom of hold 5. The corn that was located next to the engine-room bulkhead in the forward part of the hold became hot and badly damaged during the voyage. The corn located against the shaft tunnel in the bottom of the hold at the time of discharge was heating, moldy, and slightly discolored, but the remainder of the corn in the hold was discharged in good condition. As is seen in figure 59, the damaged corn next to the engine-room bulkhead had the highest temperature at the upper part of the bulkhead and the temperature decreased toward the bottom of the hold, also toward the center of the hold. Thermometers 29, 37, and 41, located next to the engine-room bulkhead near the surface, halfway down, and near the bottom of the hold, indicated a rapid increase in temperature from the first day that the corn was in the hold. Thermometer 29, which was located opposite the engine-room bulkhead, near the surface of the corn, did not show as high a temperature during the voyage or at the time the corn was discharged as thermometer 37, which was located next to the engine-room bulkhead halfway down in the hold; this is accounted for by the fact that thermometer 29 was inadvertently placed several feet back from the bulkhead. However, sample No. 30, which was taken from the corn the same height in the hold as sample No. 29, but in contact with the upper part of the engine-room bulkhead, shows a temperature of 145° F. Table 39 shows that the corn located next to the upper part of the engine-room bulkhead increased 113° F. in temperature and 26.2 c. c. in acidity, and decreased 7.5 pounds in test weight per bushel, 30 per cent in germination, and 87.5 per cent in sound kernels. This is in contrast with an increase of only 1° F. in temperature and 0.6 c. c. in acidity, and a decrease of only 0.25 pound in test weight per bushel, 20 per cent in germina-

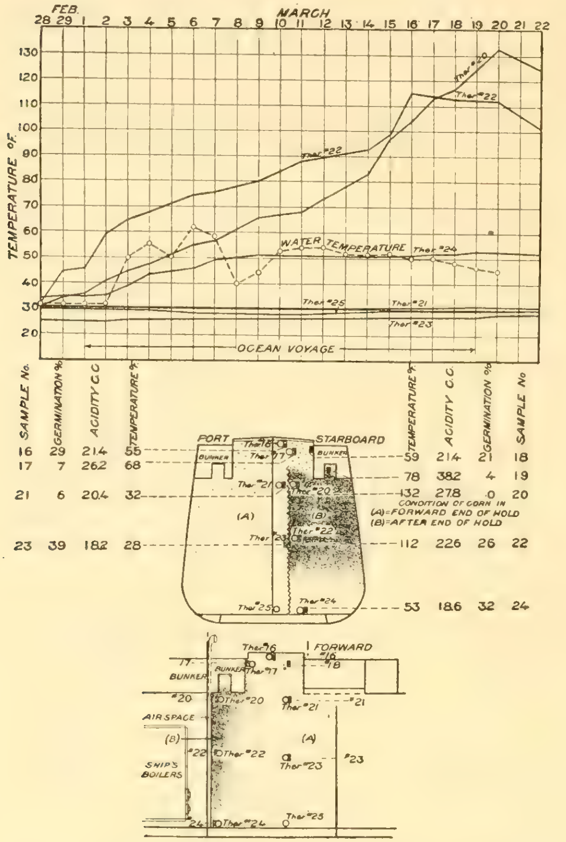

FIG. 57.—Hold 3: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 8.)

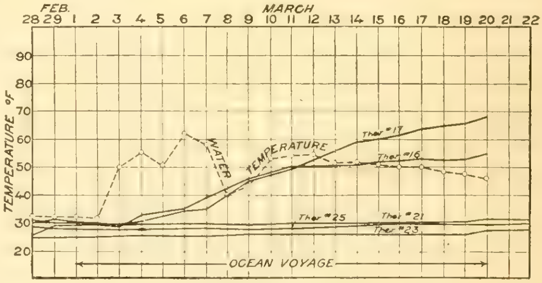

FIG. 58.—Temperature records of the thermometer located from the surface to the bottom of the corn near the center of hold 3. (Cargo No. 8.)

TABLE 39.—*Showing effect of the engine-room heat on the corn in hold 4, cargo No. 8.*

Location of corn.		Sample No.	Temperature.[1]			Moisture content as loaded.	Weight per bushel.			Germination.			Acidity.			Sound kernels.		
Height in hold.	Distance from engine-room bulkhead.[2]		As loaded.	As discharged.	+ or −		As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −
			° *F.*	° *F.*	° *F.*	*Per ct.*	*Lbs.*	*Lbs.*	*Lbs.*	*Per ct.*	*Per ct.*	*Per ct.*	*c. c.*	*c. c.*	*c. c.*	*Per ct.*	*Per ct.*	*Per ct*
Top	On ERBH	30	32	145	+ 113	20.2	53.50	46.00	−7.50	37	0	− 37	17.6	43.8	+26.2	87.5	0	−87.5
Top	12feet, ERBH.	32	31	32	+ 1	20.1	53.00	52.75	− .25	43	23	− 20	18.6	19.2	+ .6	89.5	88.7	− .8
Halfway down	On ERBH	37	32	115	+ 83	20.2	52.50	46.00	−6.50	48	0	− 48	18.8	40.4	+21.6	86.4	0	−86.4
Halfway down	12feet, ERBH.	38	29	30	+ 1	20.0	53.50	53.25	− .25	47	25	− 22	18.0	18.8	+ .8	85.9	85.7	− .2
Bottom	On ERBH	41	32	56	+ 24	20.0	52.50	51.25	−1.25	69	31	− 38	15.6	16.8	+ 1.2	83.3	82.2	− 1.1
Bottom	12feet, ERBH.	42	31	48	+ 17	20.3	52.00	52.00	0	52	25	− 27	17.6	20.2	[3]+2.6	87.9	85.4	− 2.5

CHANGE DUE TO ENGINE HEAT.

[In excess of change in corn located same height but 12 feet distant from the engine-room bulkhead.]

Top	On ERBH	......	....	....	+ 112	....	....	....	−7.25	....	....	− 17	....	....	+25.6	....	....	−86.7
Halfway down	On ERBH	......	....	....	+ 82	....	....	....	−6.25	....	....	− 26	....	....	+20.8	....	....	−86.2
Bottom	On ERBH	......	....	....	+ 7	....	....	....	−1.25	....	....	− 11	....	....	[3]−1.4	....	....	+[3]1.4

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[1] The plus (+) sign means increase, and the minus (−) sign means a decrease.

[2] ERBH=engine-room bulkhead.

[3] Greater increase in acidity, and decrease in sound kernels in sample located 12 feet back from the engine-room bulkhead was due to mold.

tion and 0.8 per cent in sound kernels for the corn located the same height in the hold but 12 feet distant from the bulkhead. The corn located against the engine-room bulkhead halfway down in the hold increased 83° F. in temperature, 21.6 c. c. in acidity, and decreased 6.5 pounds in test weight per bushel, 48 per cent in germination, and 86.4 per cent in sound kernels. This is in contrast with an increase of only 1° F. in temperature, 0.8 c. c. in acidity, and a decrease of only 0.25 pound in test weight per bushel, 22 per cent in germination, and 0.2 per cent in sound kernels for the corn located the same height in the hold but 12 feet distant from the bulkhead. The corn located against the lower part of the engine-room bulkhead was not heating, but the tests showed that it had undergone more deterioration in every factor than the corn in the lower part of the hold but 12 feet back from the bulkhead. The effect of the engine-room heat on the corn located next to the shaft tunnel is described

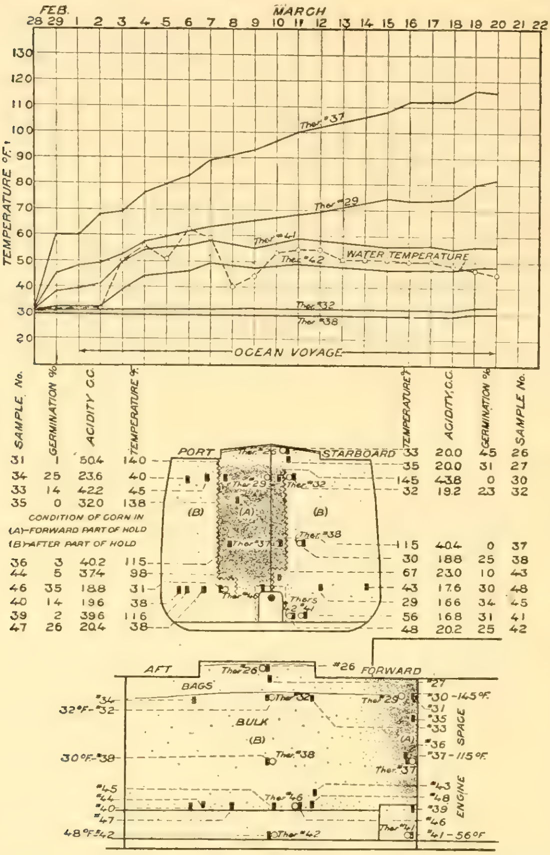

FIG. 59.—Hold 4: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 8.)

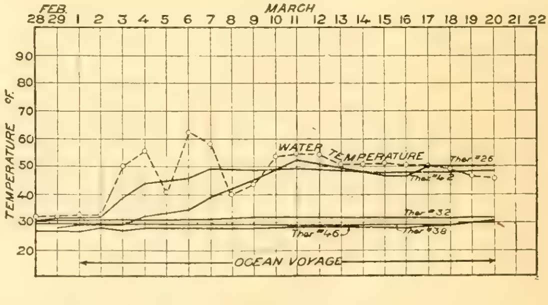

FIG. 60.—Temperature records of the corn located from the surface to the bottom of the corn near the center of hold 4. (Cargo No. 8.)

in the discussion of the condition of the corn in hold 5.

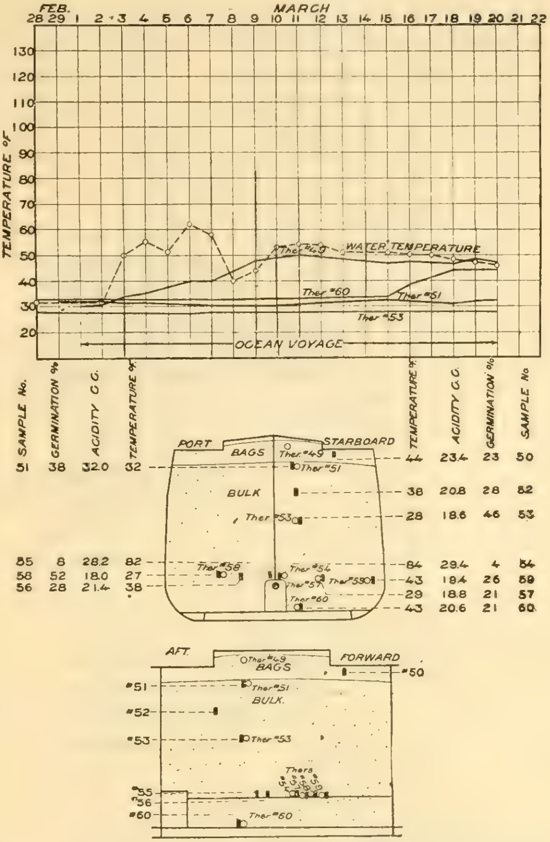

FIG. 61.—Hold 5: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Rotterdam. Heavy shading represents heat-damaged corn. (Cargo No. 8.)

The corn in hold 5 underwent very little deterioration and was discharged in good condition, excepting that portion of the corn that was stowed next to the propeller-shaft tunnel, along the bottom part of the hold, which was in a sour, moldy, and heating condition. As is shown in figure 62, the corn located directly on top of the shaft tunnel began to increase in temperature as soon as the ship got in motion at the beginning of the voyage, and the temperature increased in a regular manner during the remainder of the voyage, while the temperature of the corn stowed the same height in the hold, but halfway between the shaft tunnel and the sides of the hold, remained practically stationary during the whole voyage.

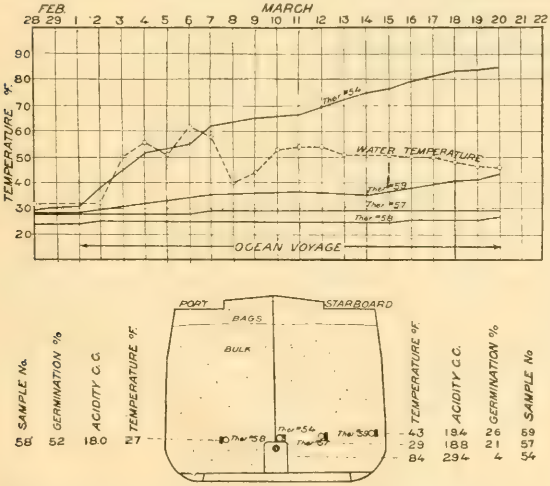

FIG. 62.—Hold 5: Showing effect of the heat from the propeller-shaft tunnel on the corn located against the tunnel. (Cargo No. 8.)

Table 40 shows that the corn located directly on top of the shaft tunnel increased 55° F. in temperature, 12.6 c. c. in acidity,

TABLE 40.—*Showing effect of the heat from the shaft tunnel on the corn in hold 5, cargo No. 8.*

Location of the corn.	Sample No.	Temperature.[1]			Moisture content as loaded.	Weight per bushel.			Germination.			Acidity.			Sound kernels.		
		As loaded.	As discharged.	+ or −		As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −	As loaded.	As discharged.	+ or −
		° F.	° F.	° F.	Per ct.	Lbs.	Lbs.	Lbs.	Per ct.	Per ct.	Per ct.	c. c.	c. c.	c. c.	Per ct.	Per ct.	Per ct.
On top of tunnel	54	29	84	+55	19.8	53.25	48.75	−1.50	50	4	−46	16.8	29.4	+12.6	86.6	58.1	−28.5
Tunnel height, half way out	57	28	29	+ 1	20.3	52.50	52.00	− .50	41	21	−20	16.6	18.8	+ 2.2	91.6	90.5	− 1.1
Tunnel height, half way out	58	24	27	+ 3	19.5	53.25	53.25	0	61	52	− 9	17.2	18.0	+ .8	87.4	87.0	− .4
Average tunnel height, half way out		26	28	+ 2	19.9	52.87	52.62	− .25	51	36	−15	16.9	18.4	+ 1.5	89.5	88.7	− .8

CHANGE DUE TO TUNNEL HEAT.

[In excess of change in corn located same height but 10 ft. away from tunnel.]

On tunnel				+53				−4.25			−31			+11.1			−27.7

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[1] The plus (+) sign means increase, and the minus (−) sign means a decrease.

and decreased 4.5 pounds in test weight per bushel, 46 per cent in germination and 28.5 per cent in sound kernels. This is in contrast with an average increase of only 2° F. in temperature and 1.5 c. c. in acidity, and a decrease of only 0.25 pound in test weight per bushel, 15 per cent in germination, and 0.8 per cent in sound kernels for the corn located the same height in the hold but 10 feet distant from the shaft tunnel.

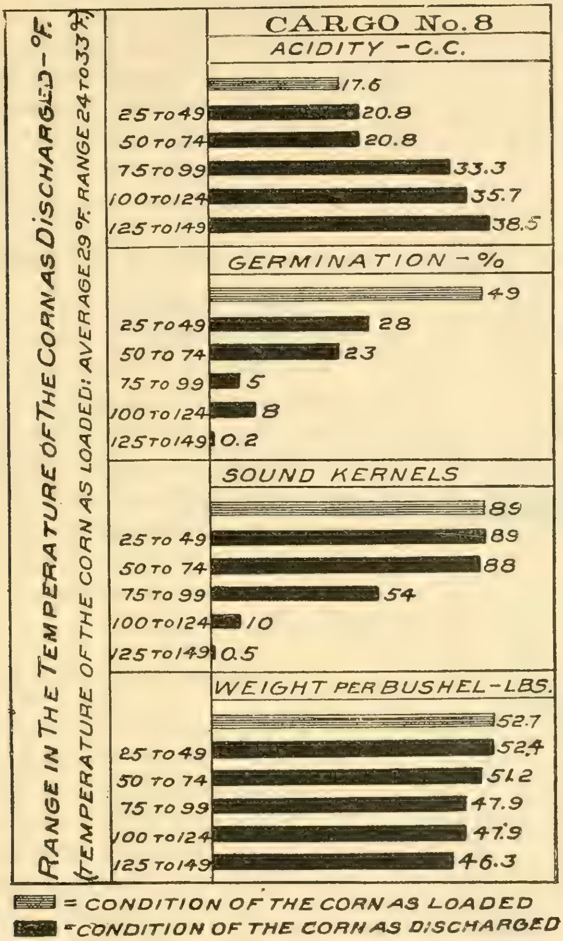

FIG. 63.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 8.)

The correlation of the temperature changes and the changes in condition of the corn is illustrated in figure 63.

CARGO No. 9.

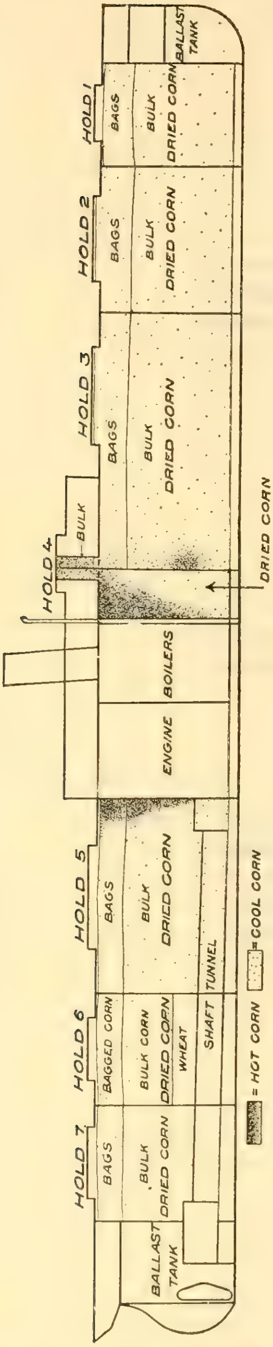

FIG. 64.—Diagram showing the arrangement of the steamship and the stowage of the corn in holds. The heavy shading represents heat-damaged corn as discharged. (Cargo No. 9.)

Cargo No. 9 consisted of 268,682 bushels of artificially dried corn. The corn was loaded April 11 to 15, 1912. The steamship sailed April 16 and arrived at Liverpool, England, on May 2, where the corn was discharged from May 3 to May 10. The length of the ocean voyage was 17 days. The maximum time any of the corn was in the vessel was 30 days, and the average time was 24 days.

STOWAGE OF THE CORN.

The steamship had seven cargo holds and, as is shown in figure 64, each hold was entirely filled with corn. Hold 6 had 20,000 bushels of wheat stowed in the lower part of the hold, the upper portion of the hold being filled with corn. Hold 4 was located just forward of the boiler room and hold 5 was located just aft of the engine room. The propeller-shaft tunnel extended along the bottom of holds 5, 6, and 7.

CONDITION OF THE CORN AS LOADED.

All of the corn in this cargo had been artificially dried before loading. The condition of the corn as loaded is shown in Tables 41 and 42. The averages for the various factors of the corn as loaded were as follows: Moisture content 17 per cent, acidity 19.9 c. c., germination 37 per cent, sound kernels 91 per cent, test weight per bushel 53 pounds. The average temperature of the corn as loaded was 51° F. It will be noted from the tables and charts that although the average moisture content at the time of loading was relatively low, it still was not low enough to insure the carrying of the corn safely in all parts of the vessel. In this connection it will be recalled that this shipment was made during the spring months of April and May.

TABLE 41.—*Range in the principal factors showing quality and condition of the corn in cargo No. 9, as loaded and as discharged, by holds.*

Holds.	Temperature.	Moisture content.	Acidity.	Germination.	Sound kernels.	Weight per bushel.
	° F.	*Per cent.*	*c. c.*	*Per cent.*	*Per cent.*	*Pounds.*
Hold 1:						
As loaded	43.0– 49.0	16.5–17.7	18.6–21.4	30.0–34.0	88.6–92.5	52.50–53.25
As discharged	44.0– 57.0	....	19.0–22.8	21.0–31.0	63.5–92.7	52.00–53.50
Hold 2:						
As loaded	49.0– 50.0	16.6–17.5	17.2–23.2	16.0–47.0	85.4–93.2	52.25–53.75
As discharged	49.0– 61.0	....	18.0–20.6	14.0–49.0	94.6–92.4	52.75–53.75
Hold 3:						
As loaded	47.0– 59.0	17.1–17.9	17.9–26.6	25.0–45.0	85.9–94.9	51.50–54.00
As discharged	46.0–122.0	....	19.8–40.0	0–38.0	40.0–93.7	47.00–54.25
Hold 4:						
As loaded	47.0– 62.0	16.0–17.4	17.0–22.4	16.0–45.0	89.1–94.7	52.00–53.50
As discharged	54.0–140.0	....	19.4–35.8	0–45.0	0–94.0	48.25–54.25
Hold 5:						
As loaded	48.0– 59.0	16.4–17.1	17.0–21.6	33.0–48.0	89.3–94.3	52.50–54.00
As discharged	48.0–121.0	....	17.0–32.8	0–44.0	4.3–93.2	49.25–54.00
Hold 6:						
As loaded	46.0– 59.0	16.8–17.0	20.4–21.4	35.0–43.0	87.1–89.2	52.00–54.00
As discharged	52.0– 56.0	....	20.2–26.8	10.0–43.0	70.6–89.6	50.00–54.25
Hold 7:						
As loaded	43.0– 55.0	16.9–17.7	17.4–21.2	24.0–43.0	90.7–93.2	53.50–54.50
As discharged	45.0– 61.0	....	19.6–26.0	29.0–45.0	90.8–93.6	53.25–54.25

TEMPERATURE CHANGES DURING THE VOYAGE AND CONDITION OF THE CORN AS DISCHARGED.

During the voyage, the corn in this cargo became badly damaged next to the upper part of the bulkheads separating the corn from the boiler and engine rooms, also in the "feeder" at the upper parts of holds 3 and 4, and, to a small extent, in the after part of hold 3 and along the shaft tunnel in the bottom of holds 5, 6, and 7. The balance of the corn in the cargo was delivered in Europe in good condition. The maximum temperatures found in the corn as discharged were 57° F. in hold 1, 61° F. in hold 2, 122° F. in hold 3, 140° F. in hold 4, 121° F. in hold 5, 56° F. in hold 6, and 61° F. in hold 7. There were no facilities for making moisture tests for the samples secured at the port of discharge, and the moisture tests of the samples secured at the time of loading only are given for this cargo.

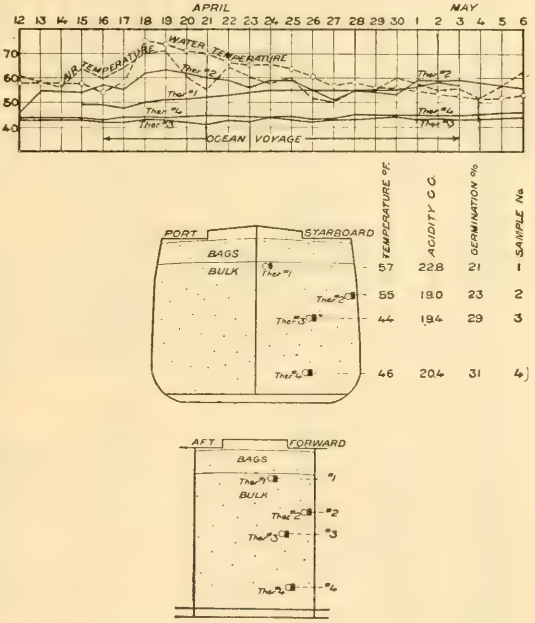

FIG. 65.—Hold 1: Temperature records of the electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

TABLE 42.—*Showing the condition of the dried corn in cargo No. 9 at the time of loading and the change in condition while the corn was in the vessel—samples taken in order in the holds from top to bottom.*

[T 1, etc., represent samples in cross-wire containers.]

Sample No.	Temperature.		Moisture content as loaded.	Acidity.		Germination.		Sound kernels.		Weight per bushel.	
	As loaded.	As discharged.		As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.	As loaded.	As discharged.
Hold 1:	*° F.*	*° F.*	*P. ct.*	*c. c.*	*c. c.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Lbs.*	*Lbs.*
T 1	49	57	17.7	21.4	22.8	34	21	88.6	63.5	53.25	52.00
T 2	46	55	17.5	18.6	19.0	31	23	92.5	92.7	53.00	53.50
T 3	43	44	16.5	21.0	19.4	31	29	92.5	92.4	52.50	52.50
T 4	44	46	16.5	20.2	20.4	30	31	89.0	88.9	52.50	52.00
Hold 2:											
T 5	49	61	16.6	20.6	19.4	16	14	88.5	87.8	53.25	53.25
T 6	50	53	17.1	21.4	20.6	40	49	85.4	84.6	52.25	53.00
T 7	50	53	17.3	23.2	18.2	40	31	89.6	92.1	53.00	53.75
T 8	49	49	17.5	17.2	20.2	47	40	93.2	92.4	52.75	52.75
T 9	50	54	17.0	19.2	18.0	42	32	91.5	92.1	53.75	53.00
Hold 3:											
T 10	47	70	17.9	17.9	23.0	25	0	88.2	54.0	52.50	51.50
11		106			28.4		14		61.0		50.50
T 12	59	61	17.5	22.2	22.0	44	22	86.8	86.6	52.75	52.25
T 13	55	59	17.6	26.6	24.2	32	21	85.9	83.9	51.50	51.25
T 14	54	48	17.7	19.0	19.8	45	21	92.2	92.2	54.00	52.50
T 15	50	47	17.5	20.2	21.0	45	34	94.5	91.7	53.00	53.00
T 16	55	57	17.7	21.8	20.8	34	36	88.4	92.3	52.50	52.25
T 17[1]	50	50	17.1	21.8	31.0	38	38	92.1	69.1	52.50	49.00
18		122			40.0		3		40.0		47.00
19	50	46	17.2	19.6	21.8	33	28	94.9	93.7	53.00	53.50
Hold 4:											
T 20	48	135	17.0	19.0	33.6	34	0	89.1	15.7	53.00	50.25
T 21	47	139	17.0	19.0	28.4	45	0	92.1	0	52.25	49.50
22		102			27.2		2		36.8		49.25
23			17.0	18.6	30.2	41	2	92.0	44.9	53.50	
24		140			25.8		0		0		48.75
25		62			23.8		31		92.2		53.75
26		132			35.8		0		0		48.25
T 27	55	54	17.3	20.0	20.8	38	26	94.7	94.0	52.50	54.25
T 28	53	60	16.2	18.2	22.8	28	15	94.2	94.0	53.00	53.00
T 29	49	70	17.2	18.0	22.6	45	18	93.1	93.7	52.00	53.00
T 30	56	69	17.4	22.4	22.2	16	10	90.7	90.5	53.25	52.00
31		61			21.6		21		84.4		52.50
T 32	62	58	16.2	17.0	20.8	43	42	92.9	91.2	52.25	53.25
T 33	61	57	16.0	18.6	19.4	20	45	93.8	94.0	52.50	52.75
T 34	57	62	16.5	20.6	21.2	43	36	93.7	92.7	52.00	52.75
Hold 5:											
35		112	17.1	21.6	31.0	48	4	90.6	46.7	54.00	51.75
36		121			32.8		4		56.4		48.25
37		81			21.4		34		89.2		51.75
38		100			27.6		0		4.3		51.25
T 39	53	52	16.8	17.0	18.6	36	41	92.3	93.2	53.25	54.00
T 40	51	50	16.5	18.8	17.0	46	38	90.2	88.5	54.00	53.00
T 41	51	54	17.0	19.4	22.0	33	35	93.8	90.9	53.25	53.50
T 42	59	95	16.9	20.6	22.2	39	28	89.3	88.6	53.00	51.00
T 43	55	72	17.0	19.8	22.6	33	19	89.4	86.9	52.50	51.25
T 44	50	71	16.4	18.2	27.6	36	3	92.6	53.6	54.00	50.00
T 45	48	48	17.0	18.4	19.4	38	44	92.7	92.6	53.50	54.00
T 46	51	75	16.5	19.0	21.6	35	28	94.3	91.0	53.00	52.50
Hold 6:											
T 47	59	56	16.9	21.4	26.8	35	10	87.1	70.6	52.00	50.50
T 48	51	56	16.8	20.4	21.0	38	40	88.8	88.9	53.50	54.25
T 49	46	52	17.0	21.0	20.2	43	43	89.2	89.6	54.00	52.50
Hold 7:											
T 50	55	60	16.9	18.2	19.6	36	45	93.2	91.7	54.50	54.25
T 51	46	55	17.7	21.2	26.0	24	29	90.7	90.8	53.50	54.25
T 52	43	45	17.6	18.8	21.2	30	37	92.5	93.6	54.50	53.75
53	50		17.0	17.6		37		91.9		54.50	
T 54	48	61	16.9	17.4	23.6	43	27	92.0		54.00	53.25

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[1] This sample was principally dirt and broken corn, evidently a representative sample of only a few bushels.

The corn in holds 1 and 2 showed practically no change during the voyage and was discharged in sound condition. The temperature records for the thermometers located in the various positions in these holds are illustrated in figures 65 and 66.

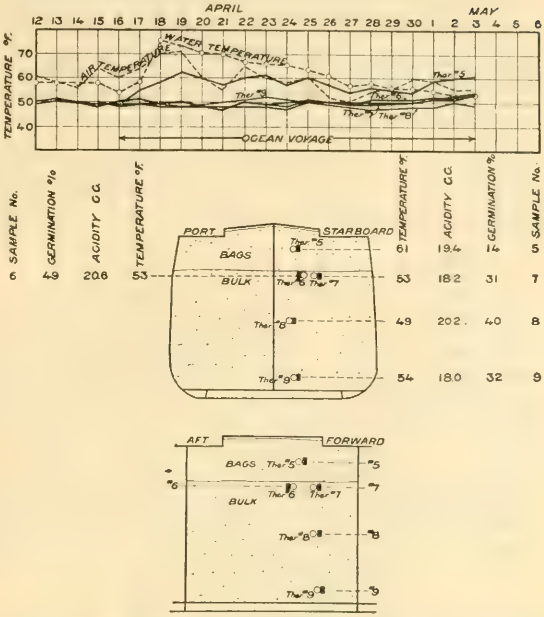

FIG. 66.—Hold 2: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

Hold 3 had one cargo hold between it and the boiler room, and, although the corn had been artificially dried before loading and there was no opportunity for the heat from the boiler to penetrate this hold, still some of the corn became hot and damaged during the voyage. It will be noted from Table 42 that some of the samples secured at the time of loading tested the highest in acidity (26.6 c. c.) of any samples in the cargo that were secured at that time, showing that at least some of the corn in this hold had undergone considerable deterioration before it was loaded into the hold and was in a dangerous condition for export, with an average moisture content

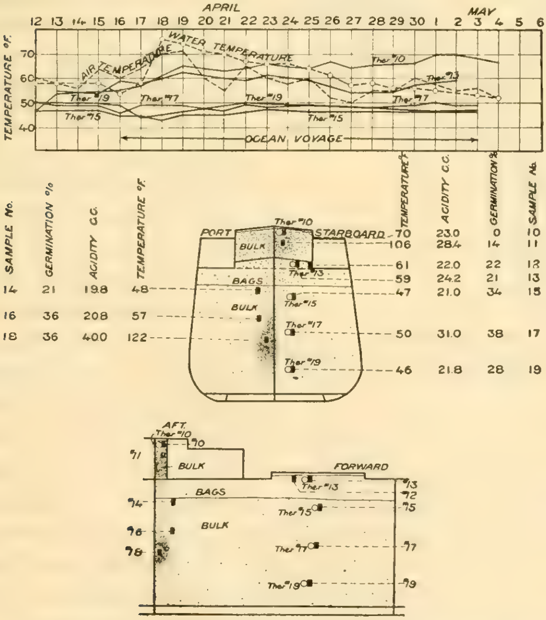

FIG. 67.—Hold 3: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

of over 17 per cent when shipped during April and May. The damaged corn was found in the after part of the hold near the shifting boards about halfway down in the hold, also in the feeder which extended down one deck from the top of the corn under the hatchway. This is illustrated in figure 67.

Hold 4 was located just forward of the boiler room. The corn located next to the boiler-room bulkhead became badly heat damaged during the voyage, the greatest heat and the most severe damage being found at the surface of the corn. There were no thermometers located immediately against the boiler-room bulkhead, but thermometer 21, located even with the top of the boiler room halfway back in the hold registered a rapid increase in temperature from the beginning of the voyage. There was a small air space under the deck and above the corn, extending from the feeder in the forward part of the hold to the upper part of the boiler-room bulkhead, and, as soon as full steam was gotten up in the boilers at the beginning of the voyage, the heat generated in the boiler room penetrated the bulkhead and was transmitted to the corn, where fermentation was started and accelerated until the temperature of the corn at this position of stowage had increased from slightly under 50° F. at the beginning of the voyage on April 16, to over 140° F. April 29, an increase of over 90° F. in temperature in 13 days, as is shown in figure 68. The condition of the corn in the various positions of stowage in the hold as loaded and as discharged is given in Table 42.

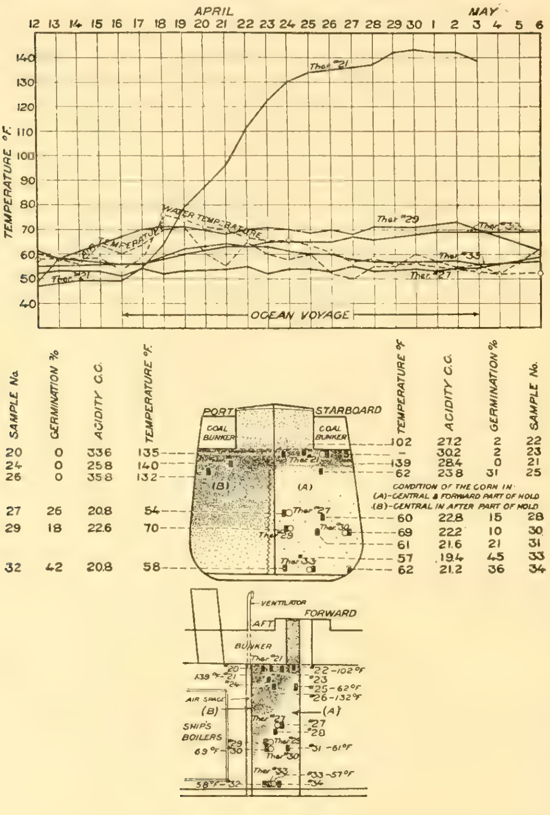

FIG. 68.—Hold 4: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

Hold 5 was located just aft of the engine room. The corn located next to the engine-room bulkhead became hot and badly damaged during the voyage. As is usual, the greatest heat and the most severe damage were found next to the upper part of the engine-room bulkhead and less heat and less damage the further the distance back from this bulkhead, and also toward the bottom of the hold. The corn in the remainder of the hold, except that located next to the propeller shaft tunnel, changed very little and was discharged in good condition. The corn located next to the engine-room bulkhead, about 9 feet under the surface of the corn, at the time of discharge had a temperature of 121° F., tested 32 c. c. in acidity, 4 per cent in germination, and 49.25 pounds in test weight per bushel, while the corn located the same height in the hold but about 20 feet distant from the bulkhead, had a temperature of only 52° F., tested 18.6 c. c. in acidity, 41 per cent in germination, 93.2 per cent in sound kernels and 54 pounds test weight per bushel. This is shown by the analysis records for samples Nos. 36 and 39, in Table 42. It will be noted from this table that the corn which was in the center and after part of the hold was discharged in Europe in practically the same condition that it was in when it was loaded into the vessel. The location of the sound and damaged corn in this hold as discharged is illustrated in figure 69.

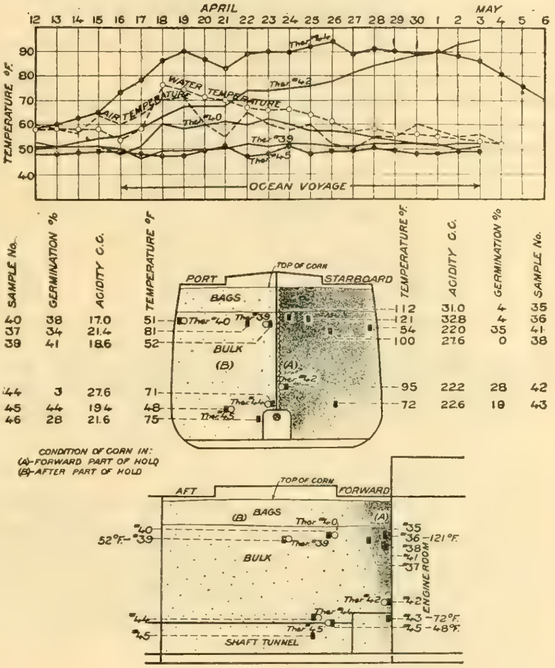

FIG. 69.—Hold 5: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

The corn in holds 6 and 7, like that in holds 1 and 2, and in the middle of the after part of hold 5, was discharged in Europe in practically the same condition that it was in at the time of loading into the vessel, except that a small amount of the corn located along the shaft tunnel in the bottom of the three after holds was somewhat musty and sour. The temperature records for the corn in the various

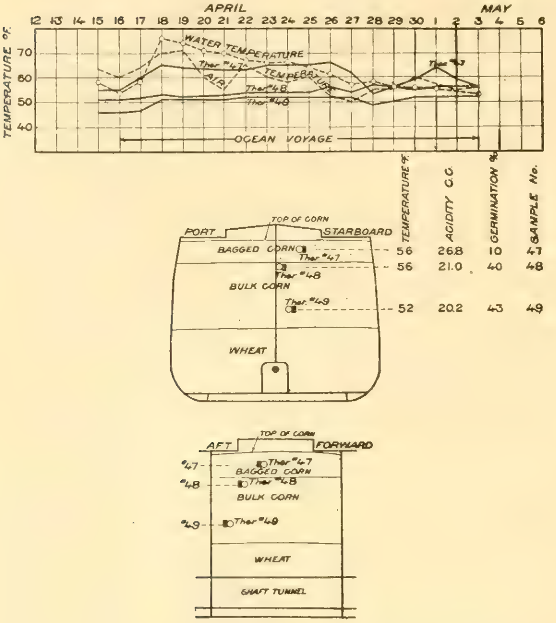

FIG. 70.—Hold 6: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

positions of stowage in holds 6 and 7 are illustrated in figures 70 and 71.

The correlation of the temperature changes and the changes in the condition of the corn is illustrated in figure 72.

SUMMARY.

The results of these investigations may be summarized in very few words:

(1) If the corn was dry and in a sound condition when shipped, it arrived in Europe in a like sound condition, regardless of the position in which it was stowed, the time of year in which it was shipped, or the length of the ocean voyage.

(2) But the higher the percentage of moisture in the corn when shipped, the greater was the danger of spoilage during the voyage.

(3) Various contributing causes worked with the moisture in causing spoilage. A combination of two or more contributing causes resulted in much greater spoilage than one contributing cause alone.

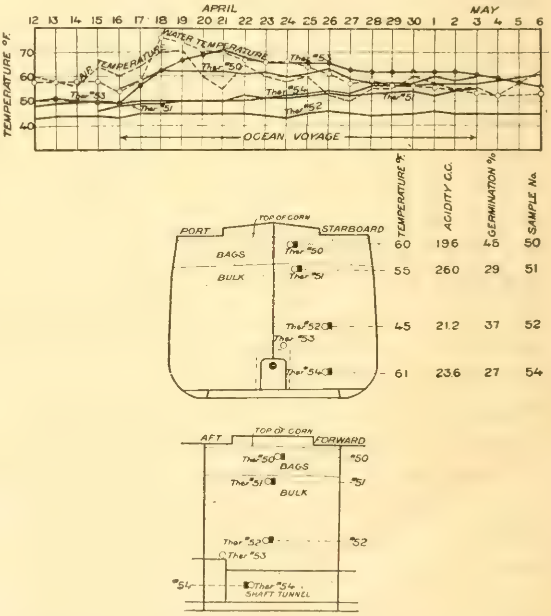

FIG. 71.—Hold 7: Temperature records of electrical resistance thermometers, location of the thermometers in the hold, and samples secured at Liverpool. Heavy shading represents heat-damaged corn. (Cargo No. 9.)

These conclusions may be verified by a study of Table 43, which is practically a summary of the entire investigation.

It may reasonably be expected, in other export shipments, if the quality and condition of the corn and the shipping conditions are similar to those found in the nine cargoes described, that the quality and condition of the corn on arrival at European ports will be the same as in those cargoes.

As the qualy, condition, and temperature of corn to be exported can be determined before it is delivered on board the vessel, and as the season the year during which shipment is to be made, the place of stowage, and the probable length of voyage are known or can be ascertained, an estimate of the condition of the corn on arrival can be made in advance.

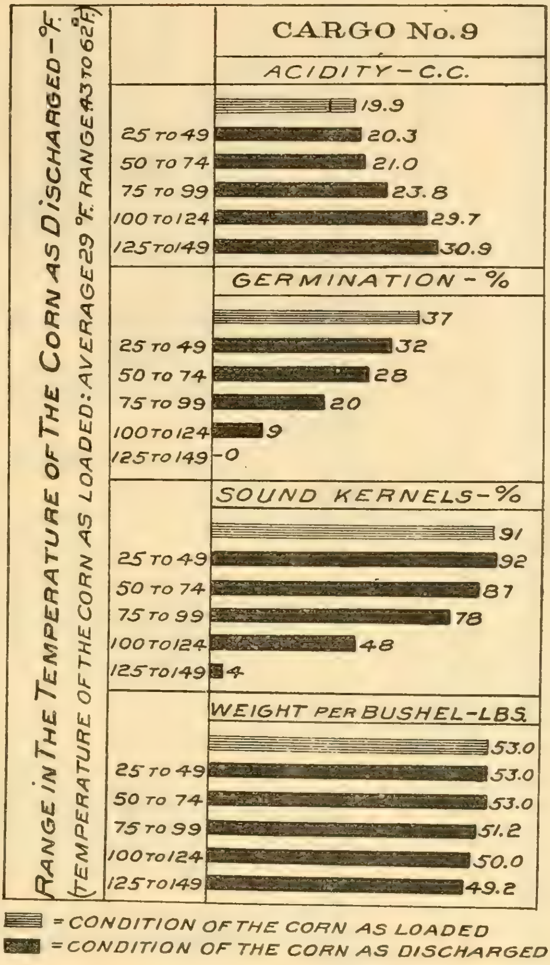

FIG. 72.—Correlation of the temperature and condition of the corn as loaded and as discharged. (Cargo No. 9.)

TABLE 43.—*Summary of the nine cargoes of corn exported to Europe, showing the average condition of the corn as loaded, by holds, stowage of the corn in the vessel, season of the year in which exported, length of the ocean voyage, average length of time that the corn was in the vessel, and condition of the corn as discharged.*

[Tun.=shaft tunnel; ER=engine room; ERBH=engine-room bulkhead; BR=boiler room; BRBH=boiler-room bulkhead.]

Cargo.	Date of sailing.	Length of ocean voyage.	Average time of corn in vessel.	Average temperature of corn as loaded.	Average moisture content of corn as loaded.	Average acidity of corn as loaded.	Stowage of the corn.			Corn reached 100° F. after sailing.	Condition of the corn as discharged.		
							Hold No.	Free from or adjacent to the ship's heat.	Location in the hold.		Maximum temperature as discharged.	Cool or heat damaged as discharged.	Location of the heat-damaged corn.
		Days.	*Days.*	° F.	*P. ct.*	*c. c.*				*Days.*	° F.		
Cargo No. 1	Mar. 8	24	34	56	18.6	25.2	1	Free	Four-fifths full	11	143	Damaged	Top, one-third of corn.
	...do	24	34	55	18.9	26.8	2	...do	Full	(1)	140	...do	Top, one-half of corn.
	...do	24	34	55	18.6	27.2	3	...do	...do	15	136	...do	Do.
	...do	24	34	59	14.7	25.8	3	...do	Middle		91	Cool	
	...do	24	34	59	18.8	28.0	4	...do	Top, one-fourth	10	148	Damaged	Total damaged.
	...do	24	34	62	14.9	22.5	4	...do	...do		80	Cool	
	...do	24	34	64	16.3	27.5	4	Next ER	Full	7	144	Damaged	Next ERBH and throughout hold.
Cargo No. 2.	Mar. 3	40	47	53	18.6	18.7	1	Free	Four-fifths full	35	110	...do	Top, one-fourth of corn.
	...do	40	47	56	18.6	19.4	2	...do	Full	11	148	...do	Top, three-fourths of corn.
	...do	[2] 33	39	70	15.5	21.9	3	Next BR	...do	13	155	...do	Top, four-fifths and on ERBH.
	...do	40	47	56	18.9	20.0	4	Next ER and Tun	...do	19	135	...do	Top, one-third on ERBH and Tun.
	...do	40	47	54	18.7	20.0	5	Tunnel	Four-fifths full	22	140	...do	Top, one-fourth and on tunnel.
Cargo No. 3	Dec. 24	14	21	32	18.7	14.0	1	Free	Bottom, one-third.		37	Cool	
	...do	14	21	31	18.6	16.0	2	...do	Bottom, one-half		39	...do	
	...do	14	21	31	18.8	16.3	3	Next bunker	Full		48	...do	
	...do	14	21	35	19.6	17.5	4	Next ER and Tun	Bottom, one-third.	(1)	132	Damaged	Along the starboard tunnel containing the steam pipes.
	...do	14	21	31	19.9	17.9	5	Tunnels (2)	...do	(1)	119	...do	Do.
	...do	14	21	30	18.8	16.3	6	...do	...do	(1)	132	...do	Do.
Cargo No. 4.	Feb. 22	14	20	36	19.5	20.5	1	Free	...do		49	Cool	
	...do	14	20	34	19.6	20.8	2	...do	Bottom, one-half		44	...do	
	...do	14	20	36	19.5	20.7	3	Next bunker	Full	(1)	118	Damaged	Opposite steam pipe along hatch.
	...do	14	20	40	20.0	20.8	4	Next ER and Tun	Bottom, one-half		79	Cool	
	...do	14	20	37	18.9	22.2	5	Tunnel	Three-fourths full		65	...do	
	...do	14	20	38	18.9	20.0	6	...do	Bottom one-half		60	...do	

Cargo No. 5.	Apr. 25	18	31	38	19.6	25.8	1	Free	Full	(1)	138	Damaged	Top one-third of corn.
	...do...	18	31	38	19.0	24.8	2	...do	...do	(1)	142	...do	Top, one-half of corn.
	...do...	18	31	38	19.3	25.4	3	Next BR	...do	(1)	140	...do	Top, two-thirds of corn and BRBH.
	...do...	18	31	38	18.7	23.4	4	Next ER and Tun	...do	(1)	140	...do	Top, one-third of corn and on BRBH.
	...do...	18	31	38	19.8	24.1	5	Tunnel	...do	(1)	138	...do	Top, one-third of corn.
Cargo No. 6.	Mar. 28	20	27	44	20.2	23.4	1	Free	...do		53	Cool	
	...do...	20	27	43	19.9	24.2	2	...do	...do	(1)	140	Damaged	Top layer.
	...do...	20	27	39	20.3	23.6	3	Next BR	...do	11	140	...do	Next BRBH and top layer.
	...do...	20	27	51	15.7	27.0	4	Next BR and Tun	...do		85	Cool	
	...do...	20	27	41	20.3	25.2	5	Tunnel	...do	(1)	120	Damaged	Top layer and along Tun.
Cargo No. 7.	Mar. 31	21	39	64	17.8	27.4	2	Free	...do	3	146	...do	Upper, one-half corn.
	...do...	21	39	63	18.4	22.3	3	Next bunker	...do	8	141	...do	Do.
	...do...	21	39	64	18.7	24.1	5	Next ERBH and Tun.	Bottom, one-half	5	147	...do	Upper, one-half and along Tun.
	...do...	21	39	62	18.7	22.4	6	Tunnel	Bottom, one-third.	16	122	...do	Upper, one-third and along Tun.
Cargo No. 8.	Mar. 1	19	21	30	20.1	18.0	1	Free	Full		46	Cool	
	...do...	19	21	30	20.1	17.7	2	...do	...do		52	...do	
	...do...	19	21	30	20.2	18.3	3	Next BR	...do	15	132	Damaged	Along BRBH only.
	...do...	19	21	30	20.0	17.5	4	Next ER and Tun	...do	11	145	...do	Along ERBH and Tun.
	...do...	19	21	29	20.1	17.0	5	Tunnel	...do		84	Cool	Out of condition along tunnel.
Cargo No. 9.	Apr. 16	17	24	46	17.0	20.3	1	Free	...do		55	...do	
	...do...	17	24	50	17.1	20.3	2	...do	...do		54	...do	
	...do...	17.	24	52	17.5	21.2	3	...do	...do	(1)	106	Damaged	Surface next to coal bunker
	...do...	17	24	53	16.8	19.1	4	Next bunker	...do	6	143	...do	Next BRBH and top layer.
	...do...	17	24	52	16.8	19.2	5	Next ER and Tun	...do	(1)	122	...do	Along ERBH and tunnel.
	...do...	17	24	50	16.9	20.9	6	Tunnel	...do		61	Cool	
	...do...	17	24	48	17.2	18.6	7	...do	...do		61	...do	

[1] No data.

[2] This cargo was discharged at two ports in Denmark and the corn in this hold was discharged at the first port.

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